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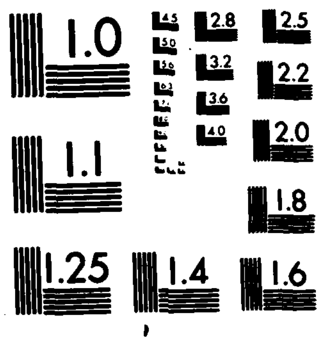

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Analysis of Existing Information on Ichthyoplankton Drift Through Dams on the Upper Mississippi River

Prepared for

U.S. Army Corps of Engineers
St. Paul District
St. Paul, Minnesota

By

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During the nid-1970's, an assessment of the potential for expanison of the nation's hydroelectric generating capabilities was initiated by the passage of the Water Resources Development Act (PL 94-587). Economic feasibility studies for small-scale hydropower development was performed for sites on the Upper Mississippi (UMR). The U.S. Fish and Wildlife Service has been asked to provide input into the final feasibility report and draft evironmental impact statements for hydropower development at Locks and Dam 5 and 8.

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The following report has these objectives: first, to compile, review, and analyze existing information movements of ichthyoplankton through dams on the UMR from above St. Anthony Falls to Lock and Dam 14. Secondly, to identify information gaps about ichthyoplankton drift and UMR fisheries in general that would prevent accurate assessment of the impacts of small-scale hydropower development on UMR fisheries; and also to identify impact assessment techniques, approaches, and means of obtaining the ncessary data for an assessment of the impacts of small-scale hydropower development on ichthyoplankton and UMR fisheries.

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1. INTRODUCTION

Study Background and Objectives

During the mid-1970's, an assessment of the potential for expansion of the nation's hydroelectric generating capabilities was initiated by passage of the Water Resources Development Act (Public Law 94-587). Section 167 of the act authorized the National Hydropower Study which was to appraise the potential of new hydropower development at existing dams as well as the potential of presently undeveloped sites. In 1977, the U.S. Department of Energy established the Small-Scale Hydroelectric Development Program to stimulate and evaluate development of small-scale hydroelectric systems with specific generating capabilities of 30 MW or less. Because of this strong legislative thrust, economic feasibility studies of small-scale hydropower development were performed for sites on the Upper Mississippi River (UMR). Economic feasibilities for hydropower development were identified at Lock and Dam Nos. 5, 7, and 8. However, reconnaissance reports for these sites also indicated that more detailed studies would be needed before development was justified.

Completion of the final feasibility report and draft Environmental Impact Statements (EIS) for Locks and Dams 5 and 8 are scheduled for completion by September 1985. The U.S. Fish and Wildlife Service has been asked to provide input to these reports. The following report has the following objectives: to compile, review, and analyze existing information on movements of ichthyoplankton through dams on the UMR from above St. Anthony Falls to Lock and Dam 14. Secondary objectives include (1) identification of information gaps about ichthyoplankton drift and UMR fisheries in general that would prevent an accurate assessment of the impacts of small-scale hydropower development on UMR fisheries; and (2) identification of impact assessment techiques, approaches, and means of obtaining the necessary data for an assessment of the impacts of small-scale hydropower development on ichthyoplankton and UMR fisheries.

Environmental Concerns Related to Ichthyoplankton Drift

Concern over the impacts of small-scale hydropower development on the downstream passage of early-life stages of fishes has been emphasized in discussions on anadromous species of the West Coast (CRFC 1981) and of the Northeast (Ruggles 1980; Loar 1982). There is strong evidence that hydropower facilities can significantly affect survival of salmonids (Raymond 1976; Salo and Stober 1977; Loar 1982) when these fishes move downriver as part of their anadromous cycle. However, direct extrapolation of the effects of hydropower development on the recruitment of these species to the recruitment of nonanadromous, warmwater species of the upper Mississippi River is probably invalid.

The systematic movement of young fishes from spawning habitats to rearing and adult habitats has not been well documented for species of the UMR but it certainly is not as dramatic as that exhibited by anadromous species. However, information on the drift, or passive transport by water currents, of fish eggs and larvae in lotic ecosystems is well documented and has proved important in discussions of the impacts of pump storage and once-through, cooling electric generating facilities on fish recruitment (e.g., Snyder 1975, Nalco Environmental Sciences 1977, Hazleton Environmental Sciences Corp. 1978, Commonwealth Edison and Environmental Research and Technology, Inc. 1980, Environmental Research and Techology, Inc. 1981). Whether fish larvae drift as a function of predator avoidance (Gale and Mohr 1978), disorientation (Larimore 1975), or of a search for nursery habitats (Manteifel et al. 1978), or some other factor, ichthyoplankton can make up a major portion of the total (invertebrate and vertebrate) drift (Clifford 1972).

The ichthyoplankton is made up of eggs, larvae, and at times juveniles. Although larval stages often predominate, eggs can exceed larval abundance in the drift at times. Specific information on species in the larval drift will be provided later in this report. Of the species of fish that inhabit the upper Mississippi River, only a few have pelagic eggs. Eggs of goldeye, *Hiodon alosoides*, are semi-buoyant (Battle and Sprules 1960). Its congener mooneye, *H. tergisus*, also has semi-buoyant eggs. The burbot, *Lota lota*, has a more or less pelagic egg (Fabricius 1954). The UMR is at the southern extreme of the burbot's range and little successful reproduction seems to occur. Eggs of the Chinese grass carp, *Ctenopharyngodon idellus* are very buoyant and may be transported 100 or more miles downstream before hatching, but no evidence of grass carp reproduction has been reported in the region. None of these species is particularly abundant in the UMR. However, eggs of the freshwater drum, *Aplodinotus grunniens*, are very abundant in the ichthyoplankton drift, often in numbers that exceed the total number of larval fish. Clearly, those species with both eggs and larvae in the drift would be particularly susceptible to impacts of small-scale hydropower development.

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2. COMPILATION OF EXISTING INFORMATION ON ICHTHYOPLANKTON DRIFT

In order to evaluate probable impacts of hydropower development on ichthyoplankton and recruitment, it was necessary to compile the existing information on general ichthyoplankton drift in the UMR and to examine species, spatial, temporal, and diel variations in the drift patterns found in main channel habitats. Much of the available data on egg, larval, and juvenile fishes specific to the UMR has been compiled by Holland and Huston (1983). That report listed geographical locations of studies, sponsors, general sampling designs, and provided an abstract of methods and results. Holland and Huston (1983) reviewed early life stages in all habitats, not specifically drift in main channel waters. No specific data were presented that could be applied directly to an evaluation of hydropower impacts on ichthyoplankton.

To accomplish the task of compiling existing data on main channel ichthyoplankton drift, the references listed in Holland and Huston (1983) and other sources were examined, and raw data sets were extracted. The data were then re-organized into standardized tables and figures to provide evaluations of pool to pool, seasonal, diel, and species-specific impacts.

Ichthyoplankton abundance was examined, in one form or another, in 10 of the 16 pools included in the scope of this study (Table 1). The vast majority of the work reported in the study was performed as part of power plant siting or monitoring programs of Northern States Power Company, Dairyland Power Cooperative, and Commonwealth Edison Company. The remainder of the reported research was performed by the U.S. Fish and Wildlife Service. Brief narratives of the studies referenced in Table 1 follow.

Table 1. Studies of ichthyoplankton drift in the upper Mississippi River from above St. Anthony Falls Lock to Lock and Dam 14 reported by navigation pool and year.

Pool	Agency	Start/stop	Location	Gear	General sampling design
Above St. Anthony Falls Lock					
1977	Northern States Power Company	May 2/July 4	Sherburne Company Generating Plant, 5 miles north of Monticello, Minnesota	modified tows/stationary net combination	samples day/night once per week; three stations in transect across the river from the plant intake; replicate samples
1976	Northern States Power Company	April/August	Monticello Nuclear Generating Plant, Monticello, Minnesota	stationary nets	entrainment monitoring in plant intake bays (surface, mid-depth, bottom) and upstream (surface, mid-depth, and bottom); collected every 4 hours on one 24-hour period, every week
Pool 1					
1980	Northern States Power Company	mid-April/mid-August	Riverside Generating Plant, River mile (RM) 857.0	stationary nets	entrainment monitoring; surface, mid-depth, and bottom in intake bays; surface tows in river; every 4 hours on one 24-hour period, every week
Pool 3					
1978	Northern States Power Company	June 6/June 17	Prairie Island Nuclear Generating Plant, Rm 798.0	towed; .560 mm-mesh net	three stations-main channel, main channel border, and mouth of Sturgeon Lake; replicated oblique tows; samples taken between 2400 and 0400
Pool 5					
1983, 1982, 1981	Dairyland Power Cooperative	late April/mid-August	Alma, Wisconsin, Rm 751.1	stationary set; 0.5 m conical net; .500 mm-mesh	five stations along transect traversing main channel; main channel samples at surface, mid-depth, and bottom; other stations had only surface samples; all sampling at dusk
1980	Dairyland Power Cooperative	June 17/June 18	Alma, Wisconsin, Rm 751.1	stationary set; 0.5 m conical net; .500 mm-mesh	24-hour sampling every 6 hours at above transect
1980	Dairyland Power Cooperative	May 1/August 15	Alma, Wisconsin, Rm 751.1	stationary set; 0.5 m conical net; .500 mm-mesh	five stations along transect traversing main channel; main channel samples at surface, mid-depth, and bottom; other stations had only surface samples; all sampling at dusk
1976, 1975	Dairyland Power Cooperative	March 10, 1975/March 30, 1976	Alma, Wisconsin, Rm 751	stationary set; 1.0 m conical net; .423 mm-mesh	net set in front of intake screens twice per week for 30 minutes or directly from Pump #3; 24-hour sampling in April
Pool 7					
1981	U.S. Fish and Wildlife Service	March/August	Rm 703.0, 706.5, 708.4, 709.5, 714.0	towed conical 1-meter net; .500 mm-mesh	five transects with main channel (surface and bottom), main channel border, and backwater stations; total 5 MC, 5 MCB, 3 BW sites; biweekly; midday
1981	U.S. Fish and Wildlife Service	May/July	Rm 706.5	in-net flow meter towed conical 1/2-meter net; .500 mm-mesh	main channel (S, B), main channel border, and backwater stations sampled every 6 hours over 24-hour period once in May, June, and July; duplicate samples
Pool 8					
1982	U.S. Fish and Wildlife Service	May/August	Rm 697 and 696	towed conical 1/2-meter net; .500 mm-mesh	two main channel, four MCB, three BW, one chute, and one tributary stations; surface only; midday; once every week
Pool 9					
1980	Dairyland Power Cooperative	February/September, 1979; February/June, 1980	Genoa Generating Station, Rm 678.5	stationary set; 0.5 m conical net; .500 mm mesh; and dip net/bucket	ichthyoplankton grab samples on opposite shores; weekly main channel surface drift samples; four stations across main channel, weekly 24-hour entrainment monitoring; samples collected from intake pipe
1975	Dairyland Power Cooperative	March/June	Genoa Generating Station, Rm 678.5	stationary sets (1-meter; .423 mm mesh) and diaphram pump	in March and April net set in front of Genoa #3 intake for 30 minutes - 24 hours; May, June - diaphram pump used to pump behind intake screen
Pool 11					
1976, 1975	Dairyland Power Cooperative	April, 1975/April, 1976	E. J. Stoneman Generating Station; Rm 606	stationary 1 meter net; .423 mm mesh	samples pumped from in front of the condenser; weekly collections over 24-hour period
Pool 14					
1981	Commonwealth Edison Company	April/July	Quad-Cities Generating Station; Rm 514.1	towed 0.5-meter net; .500 mm-mesh	weekly subsurface and bottom samples, both morning and afternoon tows taken; one MCB transect along Illinois shore just north of station
1980	Commonwealth Edison Company	April/July	Quad-Cities Generating Station; Rm 514.1	towed 0.5-meter net; .500 mm-mesh	weekly subsurface and bottom samples, both morning and afternoon tows taken; one MCB transect along Illinois shore just north of station
1979	Commonwealth Edison Company	April/July	Quad-Cities Generating Station; Rm 506.8, 514.1, 522.5	towed 0.5-meter net; .500 mm-mesh	morning, afternoon; replicated; subsurface and bottom; six stations - MCB near Illinois shore (as above), MCB near Iowa shore; MC: Rm 506.8, Rm 514.1, Rm 522.5
1978	Commonwealth Edison Company	May/July	Quad-Cities Generating Station; Rm 506.5, 506.8	towed 0.5-meter net; .500 mm-mesh	six regular sampling locations as above plus several additional; night sampling; weekly; subsurface and bottom; duplicate samples
1977	Commonwealth Edison Company	April/September	Quad-Cities Generating Station; Rm 507	towed conical 0.5 meter net; #0 gauge mesh	weekly replicate surface and bottom samples, both morning and night samples taken; river transect locations-two main channel and two main channel borders
1976	Commonwealth Edison Company	April/July	Quad-Cities Generating Station; Rm 507	towed conical 0.5 meter net; #0 gauge mesh	weekly replicate surface and bottom samples, both morning and night samples taken; river transect locations-two main channel and two main channel borders
1975	Commonwealth Edison Company	April/September	Quad-Cities Generating Station; Rm 507	towed conical 0.5 meter net; #0 gauge mesh	weekly sampling at 8-hour intervals for a 24-hour period; replicate surface and bottom samples taken at three sites, one main channel and two main channel border sites
1974	Commonwealth Edison Company	May/August	Quad-Cities Generating Station; Rm 507	stationary set; 0.42 m conical net; #0 gauge mesh	weekly surface sampling at one main channel location
1973	Commonwealth Edison Company	February/August	Quad-Cities Generating Station; Rm 507	stationary set; 0.42 m conical net; #0 gauge mesh	weekly surface sampling at six river transect locations
1972	Commonwealth Edison Company	May/September	Quad-Cities Generating Station; Rm 507	stationary set; 1.0 sq. ft. drift net; 37 meshes/inch	weekly replicate surface samples taken just after sunset for 1/2 to 1 hour at six river transect locations
1971	Commonwealth Edison Company	April/September	Quad-Cities Generating Station; Rm 507	stationary set; 1.0 sq. ft. or 0.75 m round drift net; 30 meshes/inch	twice monthly surface sampling taken for 1/2 to 1 hour at eight river transect locations

POOL 1

1980: Ichthyoplankton monitoring: Northern States Power Company Riverside Generating Plant.

Ichthyoplankton drift near the Riverside Generating Plant (Rm 857.0) was monitored during 1980 over a 24-hour period weekly at main channel and main channel border sites. Two stations were sampled from April 17 through May 8, while two others were sampled from May 15 through August 14. A stationary 0.5-m, .560 mm-mesh net was used. Samples were collected at 4 hours intervals by filtering at least 100 m^3 of water. Twenty-four taxonomic groups were identified in ichthyoplankton collections (Table 2). Maximum numbers of larvae occurred in early June (Figure 1). Suckers comprised the greatest percentage of the catch. A second pulse in numbers occurred in early July when young channel catfish became abundant (Figure 2). Greatest densities of drifting larvae occurred at main channel border sites. Larvae were also most abundant in surface waters. Complete data were not available for evaluation of diel periodicity but catches at night were always greatest. An estimate of the total ichthyoplankton drift past the plant was made. Data from the main channel border station was assumed to be representative of fish densities being drawn through the plant intake. Data from surface and bottom waters were averaged to provide an entrainment density estimate. Data from all stations and nets were combined to approximate the ichthyoplankton densities in the entire river load. Although this study incorporated adequate sampling periods to evaluate diel periodicity, data from a single main channel location and one main channel border site are not sufficient to provide an accurate estimate of the total drift in the river.

REFERENCE: Heberling, G., K. Mueller, and J. Weinhold. 1981. 1980 Riverside Generating Plant, NPDES Section 316b Supplement. Northern States Power Company, Environmental Sciences Section, Minneapolis, MN. 56 pp.

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POOL 3

1978: Ichthyoplankton monitoring: Northern States Power Company Prairie Island Nuclear Generating Plant.

Considerable effort has been expended to evaluate ichthyoplankton in the vicinity of the Northern States Power Company Prairie Island Nuclear Generating Plant (Rm 798.2). However, the objective of this study was to evaluate main channel drift in Pool 3. Collections were made during 1974, 1975, and 1976 in backwater habitats proximal to the plant. In 1978, three sites were established in main channel waters. Ichthyoplankton at the latter sites was monitored on 6 days between June 6 and June 17 using samples collected between midnight and 4 a.m. Replicate oblique tows were taken with a .560 mm-mesh net. Because of the limited scope of the study, the data generated are of little value in an evaluation of main channel ichthyoplankton drift. The same information was presented in two separate reports and tables representative of both papers have been included (Tables 3a, 3b). In one case, only total numbers by taxa and habitat were recorded (Table 3a); in the other, density by taxa by date were considered (Table 3b). No estimate of total drift was attempted.

REFERENCES: Henninson, Durham, and Richardson, Inc. 1979. Alternate discharge study for the Prairie Island Nuclear Generating Plant. Prepared for Northern States Power Company, Minneapolis, MN. 150 pp.

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POOL 5

1983 - 1982: Ichthyoplankton monitoring: Dairyland Power Cooperative Alma Plant.

During 1982 and 1983, ichthyoplankton samples were collected along a transect traversing the main channel in the vicinity of the Dairyland Power Cooperative Plant at Alma, Wisconsin. Samples were taken from late April through mid August with stationary sets of a 0.5-m, .500 mm-mesh net. Surface, mid-depth, and bottom collections were made in the main channel, but only surface collections were made along the border. All samples were taken at dusk. More complete information will not be available until the company's annual reports are completed.

REFERENCE: Johnston, G. L. 1983. Personal communication. Dairyland Power Cooperative, 2615 East Avenue S, La Crosse, WI 54601 (608) 788-4000.

* * * * *

1981 - 1980: Ichthyoplankton monitoring: Dairyland Power Cooperative Alma Plant.

Weekly drift samples were taken near the Dairyland Power Cooperative Plant from May 1 through August 15, 1980, from surface waters at five stations in a transect at Rm 751.4. Stationary 0.5-m, .500 mm-mesh plankton net was set for approximately 10 minutes. River flows were estimated, but these data were not included in the available literature. A total of 74 larvae, representing 8 taxa, were collected (Table 4). The family Cyprinidae comprised 68% of the total. Larval *Cyprinus carpio*

(36%) and *Notropis* spp. (30%) were abundant throughout June. Larval *Aplodinotus grunniens* (16%) was collected on June 17 and 18. Collections over the 24-hour period of June 18 and 19, 1980, were taken to coincide with peak drift. During this sampling, only surface collections were made at the three main channel border areas, but surface, mid-depth, and bottom samples were collected at the two main channel areas on 6-hour rotations. The density of larvae was calculated based on river current and not with an in-net flow meter. Analysis of the relative density of ichthyoplankton by time and habitat (Figure 3) indicated that there was considerable diel variability. Peak drift occurred at 2400 in the main channel while in main channel border waters the greatest concentrations of drift occurred at 0600.

Ichthyoplankton entrainment was also monitored at the J. P. Madgett Station (Table 5), Alma units 1-5 (Table 6), and on Pool 5 during the 1980-1981 period. Twenty-four hour samples were collected once per week by filtering a portion of the intake water through a .500 mm-mesh plankton net. The volume of water filtered was estimated by use of a weir box. Sampling from April 1 through September 4, 1980, yielded 14 individual larvae (Table 6). *Notropis* spp. were collected on April 10 and 17 and comprised 50% of the total entrainment. The remaining larvae entrained were unidentifiable. Sampling at the J. P. Madgett Station yielded 117 individual larvae (Table 5). Larval *Aplodinotus grunniens* (2%) were collected on July 8 and 22, 1980. *Pylodictus olivaris* (9%) were collected on July 22, 1980. The remaining larvae entrained were unidentifiable (89%).

REFERENCE: Dairyland Power Cooperative. 1982. Investigations concerning the use of the Mississippi River water for once-through-cooling at Alma, Wisconsin. 1980 Annual Report. Dairyland Power Cooperative, La Crosse, WI. 64 pp.

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1976 - 1975: Ichthyoplankton entrainment: Dairyland Power Cooperative Alma Plant.

Ichthyoplankton entrainment was monitored at Dairyland Power Cooperative Units 1-5 from March 10, 1975, through March 30, 1976. Samples were taken twice weekly during April, May, and June, and once weekly during the remainder of the study period. In March 1975, samples were collected by placing a .423 mm-mesh plankton net in front of the intake bar screens for approximately 30 minutes. The sampling effort was intensified from April to November to include sampling over 24-hour periods. From November to March the sampling apparatus was removed and samples obtained directly from Pump Number 3. Ichthyoplankton were entrained during May, June, July, and August (Table 7). *Morone chrysops* was the most abundant species of larvae entrained (43%) with a broad peak in density between May 28 and June 12. The family Cyprinidae (31%) peaked in early June. *Aplodinotus grunniens* made up only 10% of the total number of larvae entrained. Total drift in the river was not estimated.

REFERENCE: Wapora Inc. 1976. Alma Unit numbers 1-5 cooling water intake structure 316(b) document. Prepared for Dairyland Power Cooperative, La Crosse, WI. 83 pp.

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POOL 7

1981: Ichthyoplankton distribution: U. S. Fish and Wildlife Service, National Fishery Research Laboratory.

Ichthyoplankton samples were collected twice monthly during the spring and the summer of 1981 from a variety of habitats in Navigation Pool 7 with a towed 0.5 m conical plankton net (.5 mm-mesh). Larval fish distributions in the pool and variations in those distributions were analyzed relative to potential impacts of increased commercial navigation. Although as many as 66 species of adults have been found in the area (33 considered common), only 17 taxa were identified in ichthyoplankton collections (Table 8).

In April and May, most of the larvae were collected in main-channel and main-channel border areas next to major expanses of shallow backwaters. Densities in all main channel habitats were low in April, increased significantly in May and June, and decreased in July (Figure 4). No larvae were collected in August.

White bass, yellow perch, and crappies were the predominant larvae collected in the spring (Figure 5). Numerous catostomid larvae also were taken. In June and July, greatest total numbers of larvae were taken in the lower pool. Larval freshwater drum and gizzard shad predominated in these samples. Diel patterns of abundance varied with species and sampling location (Figures 6 and 7). Larval freshwater drum were more abundant near the surface at midnight than during the day. Common carp were most abundant in collections at dusk, whereas all other cyprinids were most abundant at dusk and dawn. Numbers of larval gizzard shad also increased slightly at dusk and dawn. Total numbers of larvae collected were greatest at dusk in main-channel and main-channel border samples; backwater areas produced the greatest catches at midnight and dawn. Seasonal, spatial, diel, and species-specific variations in larval fish abundances significantly influenced the proportion of the community potentially vulnerable to increased boat traffic through Pool 7. No estimates of total drift were made.

REFERENCE: Holland, L. E., and J. R. Sylvester. 1983. Distribution of larval fishes related to potential navigation impacts on the Upper Mississippi River, Pool 7. Trans. Am. Fish. Soc. 112:293-301.

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POOL 8

1982: Ichthyoplankton distribution: U. S. Fish and Wildlife Service, National Fishery Research Laboratory.

The distribution of ichthyoplankton in the middle stretches of Pool 8 was evaluated to determine if specific habitat or species assemblages existed and what, if any, physical, chemical, or biological parameters influence the structure of the assemblages. Larvae were collected weekly from May 5 to August 18 from sites in backwaters, the main channel, main channel borders, and a tributary using a towed .5 m, .505 mm-mesh plankton net. Twelve taxa were collected from main channel sites (Table 9), 16 from the main channel borders (Table 10), and 20 from backwaters (Table 11). Of the main channel areas sampled, the borders consistently produced the greatest catch (Figure 4). The source of water flowing into the main channel affected the ichthyoplankton assemblage at a site more than any of the water quality parameters. Backwater sites always contained greatest densities of ichthyoplankton. However, a main channel border wingdam site, which received flow from a side channel area with flooded hardwoods, also had an abundance of larvae during the spring. All other main channel stations had very low densities. As flow and influences of side channel declined, larval densities at the wingdam site also declined and the station became similar to other main channel sites. Larval crappies, white bass, and yellow perch peaked in density in early to mid-May, while shad, carp, sunfishes, and drum were most abundant in early summer (Figures 8, 9, and 10). Total ichthyoplankton drift was not estimated.

REFERENCE: Holland, L. E., M. L. Huston, and T. W. Kammer. 1983. Assemblages of larval fishes of various border habitats in the Upper Mississippi River. mimeo. Prog. Rep., Nat. Fish. Res. Lab., La Crosse, WI. 15 pp.

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POOL 9

1980: Ichthyoplankton drift and entrainment: Dairyland Power Cooperative Genoa #3 Generating Station.

An ichthyoplankton drift and entrainment study was conducted during 1980 near the Dairyland Power Cooperative's La Crosse Boiler Water Reactor (LACBWR) Genoa #3 (G-3) Generating Station, Pool 9. Ichthyoplankton drift and grab samples were collected to estimate the composition of the larval fish population in the immediate area of the generating station.

Drift samples were collected once each week from May 21 through June 25, 1980, at four sampling stations. Two stations were located in the main channel and two were on opposite shores adjacent to the plant. Sampling times varied from 10 to 45 minutes to provide an appropriate water volume depending on current velocity. Samples were collected during the day (times not specified) using a .5 m, .5 mm-mesh plankton net, except on June 25 when two samples were taken during daytime and one at night. Current velocities were estimated by measuring the time required for a bottle to float a fixed distance for determination of sample volumes. Grab samples were collected on June 18, 1979, and once each week from May 20 through June 25, 1980. A plankton net (.5 mm-mesh) and/or a bucket were used for grab sampling. Samples were collected only along the shorelines; no attempt was made to quantify the data.

Total drift of larval fish peaked on June 25. That date corresponded to the greatest drift of larval freshwater drum and cyprinids (Tables 12-15). Concentrations of cyprinids were greatest in the main channel, but freshwater drum had no distinct pattern of distribution.

Maximum abundance of larval suckers was recorded on June 3. Suckers were most abundant in grab samples along the eastern shore of the river and often made up 99% of the catch (Table 16).

Sampling for entrainment of fish eggs and larvae at LACBWR was conducted once each week for 24-hour periods from May 7 through September 10, 1979, and from March 12 through June 17, 1980. Samples were collected from water flowing through an intake pipe filter into a .5 mm-mesh plankton net suspended in a 190-liter drum. Population estimation based on these data were not attempted.

Sampling at G-3 was conducted once each week from February 26 through September 10, 1979, and from February 6 through June 30, 1980. The sampling method used at G-3 was similar to that used at LACBWR, except that data were obtained on the sample volume. The total sample volume was estimated by measuring the time required for the flow to fill a large pail. Data were reported as total entrainment of fish larvae by taxa and year (Table 17). Taxa of larvae collected in 1979, listed in order of decreasing abundance, included *Aplodinotus grunniens*, *Morone* sp., Catostomidae, Cyprinidae, *Dorosoma* sp., *Pomoxis* sp., and *Hiodon* sp. Taxa collected in 1980, listed in order of apparent decreasing abundance, included Cyrpinidae, *Morone* sp., *Stizostedion* sp., *Aplodinotus grunniens*, Catostomidae, and *Dorosoma* sp.

REFERENCE: McInerny, M. C. 1980. Impingement and entrainment of fishes at Dairyland Power Cooperative's Genoa site. M.S. Thesis. Univ. Wisc., La Crosse, WI. 111 pp.

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1975: Ichthyoplankton entrainment: Dairyland Power Cooperative Genoa Generating Station.

Monitoring of the entrainment of ichthyoplankton at the Genoa Generating Station was conducted from March through June, 1975. Samples were collected in March and April by placing a 1 meter, .423 mm-mesh plankton net in front of the Genoa #3 intake structure. Sampling time varied from 30 minutes to 24 hours. In May and June, a diaphragm pump was used to collect a known volume of water over 24 hours from behind the intake screen. Larval *Morone chrysops* comprised 95% of the total larvae entrained (Table 18). No entrainment of eggs was observed.

REFERENCE: Wapora, Inc. 1975. Studies to determine the aquatic ecological impacts of thermal discharges at the Genoa Generating Station. Prepared for Dairyland Power Cooperative, La Crosse, WI. 99 pp.

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POOL 11

1976 - 1975: Ichthyoplankton entrainment: Dairyland Power Coop. E. J. Stoneman Generating Station.

Ichthyoplankton entrainment was monitored at Dairyland Power Cooperative's E. J. Stoneman Generating Station near Cassville, Wisconsin from April through September, 1975. Random samples were collected over a

24-hour period weekly by filtering water from a condenser tube through a .423 mm-mesh plankton net mounted in a 55 gallon drum. Samples were collected from the intake tunnel by the same method from September 1975 through March 1976.

Although total densities of larval entrainment were reported, densities by species were not provided. A total of 642 individuals representing 18 species, 2 genera, and 2 families were identified (Table 19). No eggs were collected. Numbers of fish entrained per 24-hour sample ranged from 0.0 to 1.16/m^3. All fish were entrained between May 26, 1975, and November 11, 1975; the peak entrainment occurred in June 1975. *Morone chrysops* comprised over 72% of the total numbers entrained. *Aplodinotus grunniens* followed with 10%, while *Notropis* spp. represented only 5%. All other individual species represent less than 2% of the total catch. No estimate of total drift was made.

REFERENCE: Wapora, Inc. 1976. Effects of the E. J. Stoneman Generating Station on the biota of the Mississippi River. Prepared for Dairyland Power Cooperative, La Crosse, WI. 79 pp.

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POOL 14

1981: Ichthyoplankton monitoring: Commonwealth Edison Company Quad-Cities Generating Station.

Fish eggs and larvae were collected weekly from April 16 to July 28, 1981, at a main channel border site near the Quad-Cities Generating Plant. Samples were taken just below the surface and near the bottom once in the morning and once in the afternoon. Nets were towed upstream for about 3 minutes to filter a minimum of 30 m^3 of water.

Ichthyoplankton densities were greatest in both surface and bottom waters in June (Figure 11a). In all, twenty-one taxa of larvae were collected from the main channel (Table 20). Yellow perch and *Stizostedion* spp. appeared in the collections in April, followed by mooneyes, suckers, and white bass in May (Figure 12). Freshwater drum peaked in mid-June and were the most abundant species collected. Gizzard shad and common carp were next in abundance.

Eggs of freshwater drum, emerald shiners, and an unidentified species (thought to be mooneye) were collected (Table 21). No consistent pattern was observed in vertical distribution or distribution with time of day. Maximum egg densities were observed in late May and corresponded to the low-flow period and a sharp increase in temperature from 14° C to 19-20° C. No estimate of total drift was made.

REFERENCE: Environmental Research and Technology, Inc. 1982. Quad-Cities aquatic program, 1981 Annual Report (Volume 1). Prepared for Commonwealth Edison Company, Chicago, IL. 201 pp.

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1980: Ichthyoplankton monitoring: Commonwealth Edison Company Quad-Cities Generating Station.

Ichthyoplankton samples were collected weekly at Location 2 (main channel border) from April 15 through July 29 near the Quad-Cities Generating Plant. Replicate subsurface and bottom tows were taken in the morning and afternoon. Sixteen taxa of ichthyoplankton were found in the drift (Table 22). The majority of eggs collected were freshwater drum (Table 23).

Densities of larval walleye and sauger peaked in late April, followed by increases in yellow perch, darters, mooneyes, and carpsuckers in mid-May. Concentrations of shad, carp, gizzard shad, minnows, and crappies peaked in early to mid-June. Crappies and minnows showed a second increase in drift in late-June. Densities of freshwater drum larvae peaked in the period from late-June to early-July (Figure 13). The maximum abundance of larval fishes occurred in late-June to early-July (Figure 11b) and coincided with peak densities of minnows and freshwater drum.

Freshwater drum eggs were predominant in samples collected from mid-May to mid-July (Table 23). Densities of eggs increased drastically on May 27 when water temperatures first reached over 20° C. No estimate of total ichthyoplankton drift was made.

REFERENCE: Environmental Research and Technology, Inc. 1981. Quad-Cities aquatic program, 1980 Annual Report (Volume 1). Prepared for Commonwealth Edison Company, Chicago, IL. 201 pp.

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1979: Ichthyoplankton monitoring: Commonwealth Edison Company Quad-Cities Generating Station.

Sampling for larval fishes was conducted weekly from April 15 through July 31 at six locations which included three main channel sites (river cross section), two main channel border sites, and one backwater site. Replicate plankton tows near-surface and bottom were taken during the day. Thirty to 50 m^3 of water were filtered during each tow. Water temperature and flow were recorded at each location. Data on larval fish were reported as average density for all stations combined (Table 24); data on egg distribution were reported as average density at each station (Table 25).

Peak ichthyoplankton drift occurred in June at main channel and main channel border surface and bottom locations (Figure 14a). Yellow perch were the first larvae to appear in collections (April 25) and peaked in density by mid-May. There was no discernable pattern in the spatial or temporal distribution of freshwater drum eggs (Table 25). However, when adjusted for flow, more than 90% of the drum eggs passed through main channel sites by June 19, 1979. Freshwater drum larvae were first present in the drift in late-May, peaked in density in mid-June, and had a second pulse again in late-July (Figure 15).

REFERENCE: Commonwealth Edison Company and Environmental Research and Technology, Inc. 1980. Quad-Cities aquatic program, 1979 Annual Report (Volume 1). Prepared for Commonwealth Edison Company, Chicago, IL. 184 pp.

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1978: Ichthyoplankton monitoring: Commonwealth Edison Company Quad-Cities Generating Station.

In 1978, the Quad-Cities Station decreased the number of sampling locations in the vicinity of the plant to three; one main channel and two main channel border stations. Three new stations were added: two in the main channel at Rms. 522.5 and 514.1 and one backwater station in Marias D'osier Slough. Duplicate samples were collected weekly from mid-May through July at all three of the stations located in the vicinity of the plant and at the station located at Rm 514.1. Samples were taken at night from the surface and at one meter below the surface. Samples from Rm 522.5 were taken only from the end of May to mid-June. Data from Marias D'osier Slough was not incorporated because it was a backwater station. Drift densities were generally higher at main channel border than at main channel sites. Sampling during 1978 yielded 17 taxa (Table 26). Ichthyoplankton drift peaked during June in both sampling areas (Figure 14b). Larval carp, other cyprinids, catostomids, and freshwater drum comprised 94% of the drift. Drift densities of larval *Cyprinus carpio* peaked toward the end of May with a second peak in June (Figure 16). Eggs and larval *Aplodinotus grunniens* peaked in abundance in early June.

During June 19-23, the sampling effort was intensified to alternate days and expanded to include surface, subsurface, midwater, and bottom samples at each location during the day and night. The intensified sampling effort was used to determine the relative density of ichthyoplankton drift during day and night, and to quantify relative density between day and night (Figure 17). These data were used to estimate total ichthyoplankton drift in the river. ile the sampling design was sufficient for the original purpose, it .iled to provide the information needed to determine peak drift densities occurring at dawn and dusk. As a result, total drift densities were underestimated.

Data collected from 1975 to 1978 were used to estimate the total ichthyoplankton drift in the river and the total numbers entrained. However, these data were not sufficient for calculating total drift densities for the following reasons: (1) sampling times did not remain constant throughout the 4 year period and, therefore, the data can not be averaged, and (2) evaluation of diel variations in drift did not always incorporate sampling at dawn and dusk. Therefore, the reported data significantly underestimated total drift densities.

REFERENCE: Hazleton Environmental Sciences Corporation. 1978. Environmental monitoring in the Mississippi River near Quad-Cities Station May 1975 through July 1978. Prepared for Commonwealth Edison Company, Chicago, IL.

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1977: Ichthyoplankton monitoring: Commonwealth Edison Company Quad-Cities Generating Station.

Fish eggs and larvae (Tables 27, 28) were collected from four river transect locations; two in the main channel and two at main channel border sites. Weekly sampling for ichthyoplankton began the last week in April and continued through the second week in September. Samples were taken once during the day and once at night. Duplicate samples were taken near the surface and within 1 meter of the bottom. Nets equipped with flow meters were towed until approximately 30 m^3 of water was filtered.

Eighteen taxa of larvae were identified in the drift (Table 27). Peak densities of larvae occurred in early July (Figure 18a). Larval percids and crappies reached peak densities in late April (Figure 19). Densities of larval mooneye and white bass peaked in early-May; carp were most concentrated in early June. From late June to early July, numbers of larval gizzard shad, sunfish, and freshwater drum peaked. These species accounted for the peak in total larvae that also occurred at this time.

REFERENCE: Hazleton Environmental Sciences Corporation. 1978. Environmental monitoring in the Mississippi River near Quad-Cities Station May 1975 through July 1978. Prepared for Commonwealth Edison Company, Chicago, IL.

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1976: Ichthyoplankton monitoring: Commonwealth Edison Company Quad-Cities Generating Station.

Samples were collected weekly from the last week in April through the second week of September in duplicate from one meter under the surface and one meter above the bottom. Two main channel border and two main channel stations were sampled once during daylight and once during the night. Drift nets were set when current velocities were high in the spring, and towed later in the season to filter approximately 30 m^3 of water.

Fifteen taxa of larval fish (plus 28 unidentified specimens) were collected (Table 29). Peak density occurred on June 17-18. Percidae appeared first in the drift and probably were most abundant before the sampling began on April 29. Mooneye, buffalo, and crappie larvae peaked in density during May, followed by gizzard shad, minnows, suckers, white bass, and freshwater drum (Figure 20). Sunfishes peaked in mid-July.

The peak average density of eggs occurred on June 8-9 coinciding with low river levels and probably peak spawning activities (Table 30). Eggs of freshwater drum dominated the drift. Collections of eggs of this species were similar at all river transect locations and showed no great vertical or diel differences.

REFERENCE: Nalco Environmental Sciences. 1977. Operational environmental monitoring in the Mississippi River near Quad-Cities Station, February 1976 through January 1977. Annual report to Commonwealth Edison Company, Chicago, IL. 584 pp.

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1975: Ichthyoplankton monitoring: Commonwealth Edison Company Quad-Cities Generating Station.

Sampling was conducted once weekly from April 28 through September. Duplicate samples were collected within one meter of the surface and within one meter of the bottom at 8-hour intervals over a 24-hour period. Samples were taken near the Iowa shore, in the main channel, and near the

Illinois shore along a transect across the river. Nets were set when current velocities were greatest in the spring and towed later in the season to filter approximately 30 m^3 of water. Egg density data from subsurface and bottom samples, and for all times, were averaged together. Larval fish densities were presented as averages per day. The 24-hour information available was not adequate for evaluation of diel periodicity.

Egg densities (66% were freshwater drum) pulsed on May 28-29 and peaked on July 30-31. Nearly 70% of all eggs collected (dates combined) were taken at the main channel site.

Nineteen larval fish taxa were collected (837 unidentified specimens) (Table 31). Average total larval fish density peaked on June 10-11 (Figure 18c). *Stizostedion* spp. appeared in collections on May 6 and reached their peak abundance on May 20. Mooneye, buffalo, and carp also reached peak densities in May. In June, freshwater drum, white bass, other cyprinids, *Pomoxis* spp., and gizzard shad peaked (Figure 21). No significant differences were found among numbers of larvae collected at different times of the day for combined top and bottom samples.

No significant differences were determined between surface and bottom collections with time for buffalo. There were also no significant differences with time for surface samples of white bass. However, densities were greater at night than during other times of day. Carp and freshwater drum densities were greatest at night in surface collections, but were not significantly different for the various times of day in bottom collections. A combination of the data from all four of these taxa showed no significant differences in densities for various times of day for surface or bottom samples.

REFERENCE: Nalco Environmental Sciences. 1976. Operational environmental monitoring in the Mississippi River near Quad-Cities Station, February 1975 through January 1976. Annual report to Commonwealth Edison Company, Chicago, IL. 452 pp.

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1974: Ichthyoplankton monitoring: Commonwealth Edison Company Quad-Cities Generating Station.

Sampling was conducted weekly from May 8 to August 28 at a single main channel location (Location 15). A drift net (fitted with a flowmeter) was placed 8 inches below the surface and tethered with a 30 ft line.

Peak ichthyoplankton drift occurred on June 26 (Figure 22a). Although total densities were reported for each sampling date, no species-specific densities were provided but the total ichthyoplankton catch was reported (Table 32).

REFERENCE: Nalco Environmental Sciences. 1975. Operational environmental monitoring in the Mississippi River near Quad-Cities Station, August 1974 through January 1975. Annual report to Commonwealth Edison Company, Chicago, IL. 272 pp.

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1973: Ichthyoplankton monitoring: Commonwealth Edison Company Quad-Cities Generating Station.

Larval fish were collected weekly from May 10 to the end of August at locations 15 (main channel border), 17 and 18 (main channel), and 20 (main channel border). Set nets were fished at the surface for 5-15 minutes. Total densities were reported, but species specific data were restricted to total catch and, therefore, were of limited value.

Total peak densities occurred on June 14 (Figure 22b). Numbers of freshwater drum and carp dominanted the samples collected in June. Larval percids were collected in May, while *Notropis* spp. peaked in May. Gizzard shad, mooneye, white bass, and *Pomoxis* spp. peaked in June, and *Lepomis* spp. peaked in July (Table 33).

REFERENCE: Nalco Environmental Sciences. 1974. Operational environmental monitoring in the Mississippi River near Quad-Cities Station, August 1973 through January 1974. Annual report to Commonwealth Edison Company, Chicago, IL. 294 pp.

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1972: Ichthyoplankton monitoring: Commonwealth Edison Company Quad-Cities Generating Station.

Drift nets were set weekly from May 10 to September 13 and biweekly from September 20 to October 12. Nets were set in duplicate just below the surface for 1/2 to 1 hour at six locations (locations 15-20, two main channel sites and four main channel border sites). All sampling started about 1/2-hour after sunset. Densities of all taxa of larval fish are presented in Figure 22c. Species data were not reported as densities but as catch per date (Table 34). Therefore, the species-specific information is of limited value.

REFERENCE: Industrial Bio-Test Laboratories. 1973. Determination of thermal effects in the Mississippi River near Quad-Cities Station, January-July 1972, Volume II. Prepared for Commonwealth Edison Company, Chicago, IL. 400 pp.

Industrial Bio-Test Laboratories. 1973. Determination of thermal effects in the Mississippi River near Quad-Cities Station, August 1972 through January 1973. Prepared for Commonwealth Edison Company, Chicago, IL. 247 pp.

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1971: Ichthyoplankton monitoring: Commonwealth Edison Company Quad-Cities Generating Station.

Sampling was conducted biweekly from April 29 to September 22 at eight locations. Drift nets were set for 1/2 to 1-hour. Little information on the volume of water filtered was taken so densities of drifting larvae could not be determined. Catch data from all eight locations were combined and presented as numbers of fish larvae collected by date (Table 35).

REFERENCE: Industrial Bio-Test Laboratories. 1972. Determination of thermal effects in the Mississippi River near Quad-Cities Station, 1971, Volume I. Prepared for Commonwealth Edison Company, Chicago, IL. 320 pp.

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Table 2. Densities of fish larvae/100 m^3 from main channel and main channel border sites near the Northern States Power Riverside Plant in Pool 1 of the upper Mississippi River, 1980.

Species	April		May					June				July					August	
	17	24	1	8	15	22	29	5	12	19	26	2	10	17	24	31	7	14
Hiodontidae																		
Hiodon terjisus	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Salmonidae																		
Coregonus sp.	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cyprinidae	0.0	0.0	0.0	0.0	0.1	0.0	0.6	0.3	0.5	0.5	0.2	0.4	0.3	1.2	0.9	0.9	0.5	0.3
Cyprinus carpio	0.0	0.0	0.0	0.0	0.1	0.3	1.0	0.5	0.5	0.2	0.1	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Catostomidae	0.0	0.0	0.0	0.7	0.3	1.3	0.6	5.3	1.6	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Ictaluridae																		
Ictalurus punctatus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.6	0.8	3.3	2.4	0.9	0.2	0.1	0.0	0.0
Notorus gyrinus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0
Percopsidae																		
Percopsis omiscomaycus	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gasterosteidae																		
Culaea inconstans	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Centrarchidae	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ambloplites rupestris	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lepomis macrochirus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.0	0.0
Micropterus dolomieui	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.4	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Micropterus sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pomoxis nigromaculatus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pomoxis sp.	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percidae	0.0	0.0	1.9	0.7	0.2	0.3	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Etheostoma nigrum	0.0	0.0	0.0	0.3	0.1	0.1	0.2	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percina caprodes	0.0	0.0	0.0	0.1	0.0	0.3	0.3	0.6	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stizostedion vitreum	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

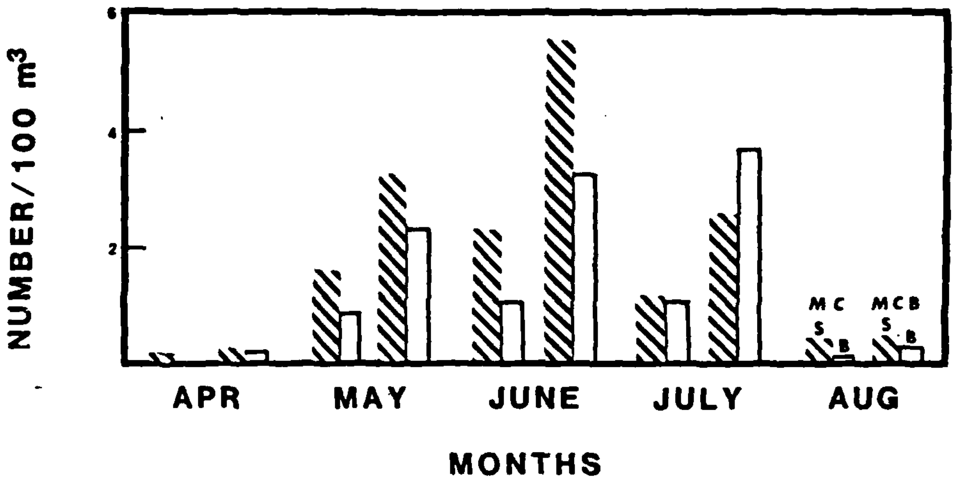

Fig. 1. Ichthyoplankton drift by month and habitat, Pool 1, 1980. MC = main channel; MCB = main channel border; S = surface; and B = bottom.

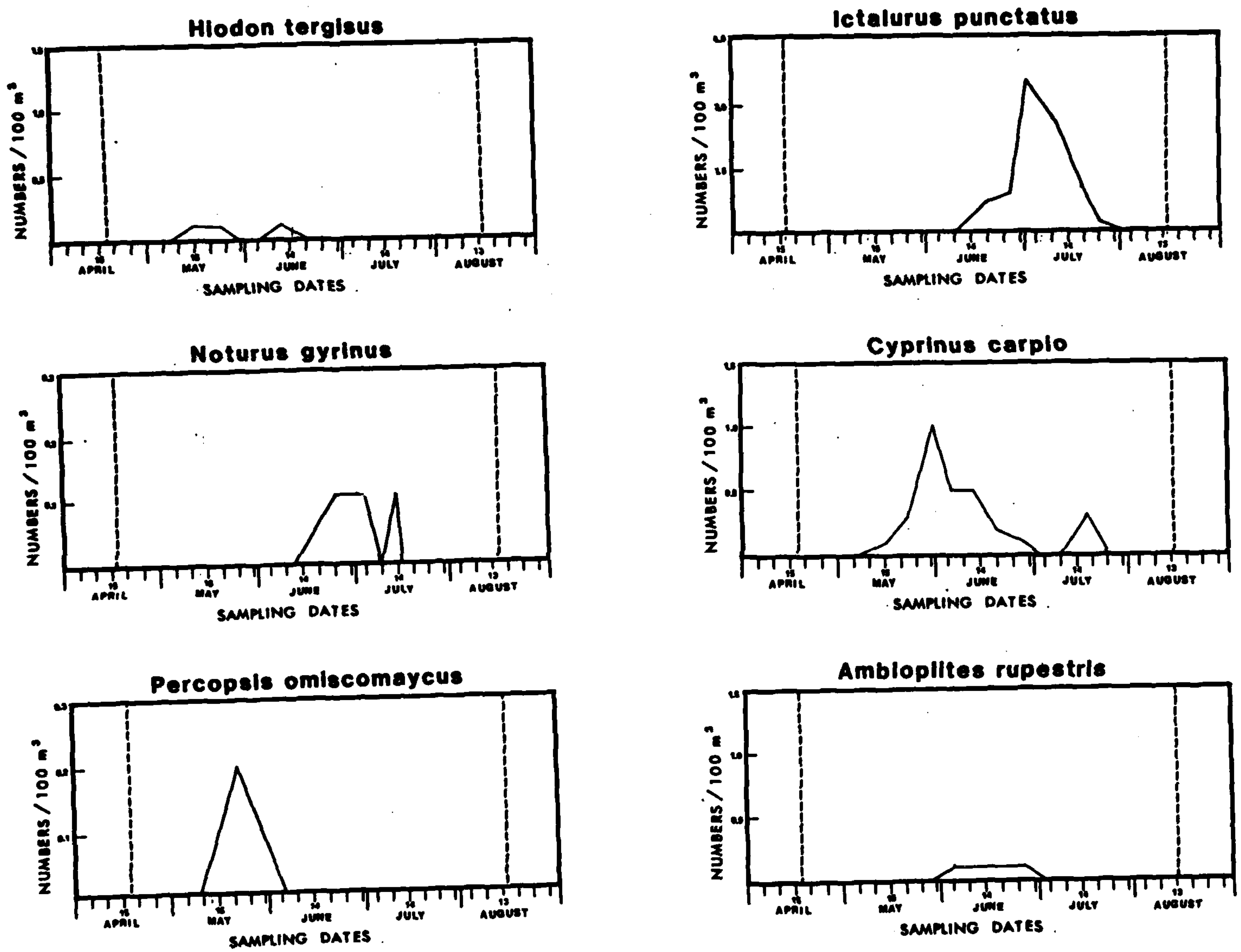

Fig. 2. Seasonal distribution of larval drift of selected species from main channel and main channel border sites in Pool 1, 1980.

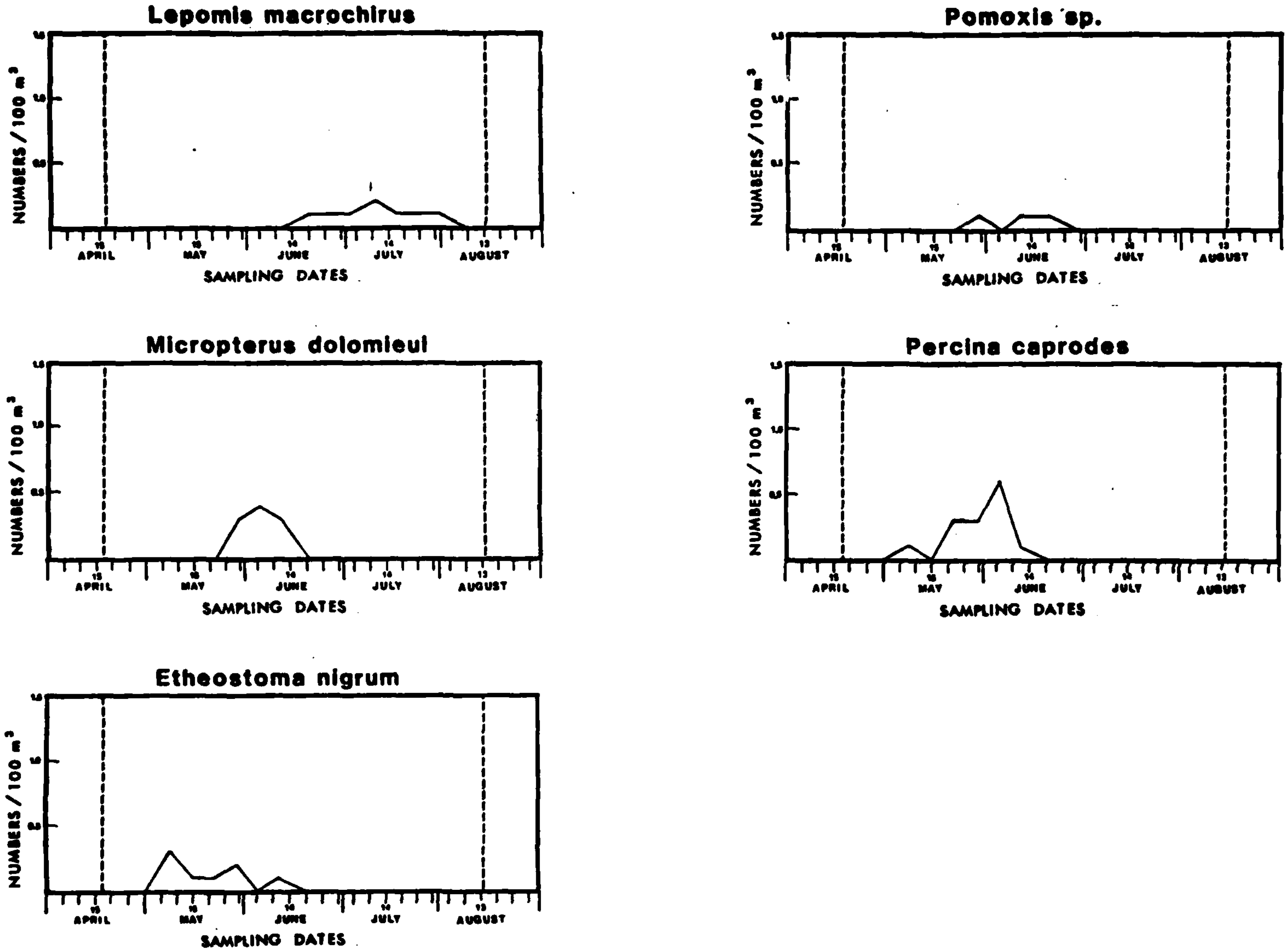

Fig. 2. Continued.

Table 3a. Total number of fish larvae collected in replicate oblique tows near the Prairie Island Nuclear Generating Plant in the main channel (MC) and main channel border (MCB) in Pool 3 of the upper Mississippi River, 1978.

Species	MC	MCB
Clupeidae		
Dorosoma sp.	677*	567
Cyprinidae		
Cyprinus carpio - larvae	92	418
- eggs	12	0
Catostomidae	61	27
Percichthyidae		
Morone chrysops	46	81
Centrarchidae	16	12
Percidae	4	1
Sciaenidae		
Aplodinotus grunniens - larvae	659	418
- eggs	1,836	1,752
Other (mainly *Notropis* sp.)	23	10
Unidentified - larvae	10	41
- eggs	273	13

* Numbers represent the sum of all sampling dates and are not per 100 m^3.

Table 3b. Densities of fish larvae/100 m^3 collected near the Prairie Island Nuclear Generating Plant in Pool 3 of the upper Mississippi River, 1978.

Species	June											
	6		8		10		13		15		17	
	MC	MCB	MC	MCB	MC	MCB	MC	MCB	MC	MCB	MC	MCB
Clupeidae *Dorosoma cepedianum*	26	18	47	24	41	14	12	22	9	15	9	14
Cyprinidae *Cyprinus carpio*	1	2	0	1	2	4	1	4	1	25	15	43
Catostomidae	0	0	0	0	1	0	2	2	2	2	8	1
Percichthyidae *Morone chrysops*	3	8	5	4	0	1	1	0	1	1	0	0
Centrarchidae *Pomoxis* sp.	0	0	0	0	1	0	1	0	1	0	0	0
Unidentified - larvae	16	13	16	11	27	25	14	9	19	15	118	24
- eggs*	41	29	195	52	56	4	61	150	63	82	15	23

* Eggs were not identified but were probably *Aplodinotus grunniens*.

Table 4. Species of fish collected from surface waters during drift sampling from five river transect sites (main channel and main channel border) in the vicinity of Dairyland Power Cooperative's J. P. Madgett Station, in Pool 5 of the upper Mississippi River near Alma, Wisconsin, 1980.

	May		June					July
Species	20	27	11	17	18	24	30	21
Clupeidae								
Dorosoma cepedianum	0	0	0	0	6	0	0	0
Cyprinidae								
Cyprinus carpio	0	0	0	0	4	22	0	1
Notropis spp.*	0	0	14	1	5	1	1	0
Unidentified minnows**	0	0	0	0	0	0	0	1
Catostomidae								
Unidentified suckers	0	0	3	0	0	0	0	0
Cypiniformes								
Unidentified cypiniformes	1	1	0	0	0	0	0	0
Centrarchidae								
Lepomis macrochirus	0	0	0	0	0	0	1	0
Sciaenidae								
Aplodinotus grunniens	0	0	0	3	9	0	0	0

* Probably *N. atherinoides*.
** Probably *Pimephales* spp.

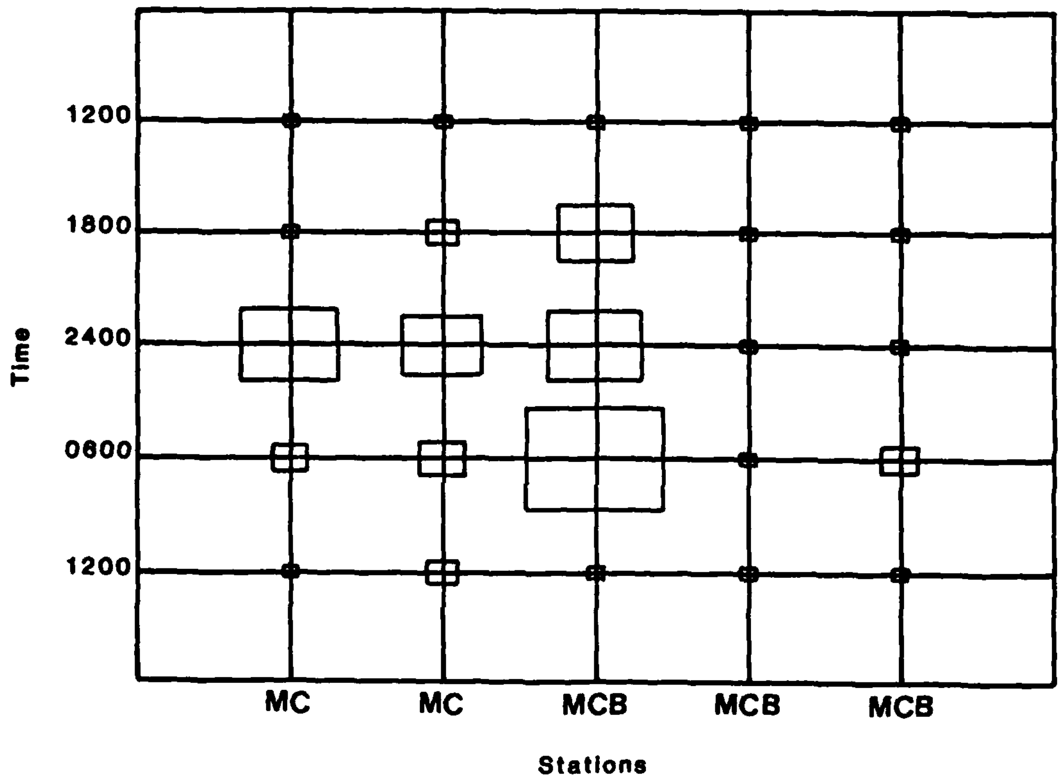

Fig. 3. Relative density of ichthyoplankton by time and habitat, Pool 5, 1980. Boxes represent comparative relative abundances (numbers/100 m^3). *MC* = main channel (*surface, mid-depth, and bottom combined*); *MCB* = *main* channel border (surface only).

Table 5. Species entrained at Dairyland Power Cooperative's J. P. Madgett Generating Station, in Pool 5 of the upper Mississippi River near Alma, Wisconsin, 1980.

	May	June			July				August
Species	28	11	19	24	8	16	22	29	6
Sciaenidae									
Aplodinotus grunniens	0	0	0	0	1	0	1	0	0
Ictaluridae									
Pylodictus olivaris	0	0	0	0	0	0	11	0	0
Unidentified*	1	0	0	0	0	0	0	0	0
Unidentified**	0	4	19	1	0	0	0	0	0
Unidentified***	0	0	0	0	3	24	36	14	2

* Probably Cyprididae or Catostomidae.

** Probably *Dorosoma cepedianum*, Cyprinidae, or Catostomidae.

*** Probably *Dorosoma cepedianum* or Cyprinidae.

Table 6. Species of fish entrained at Dairyland Power Cooperative's Units 1-5, in Pool 5 of the upper Mississippi River near Alma, Wisconsin, 1980.

Species	April 10	April 17	June 14	July 22	July 29
Cyprinidae					
Notropis spp.	5	2	0	0	0
Unidentifiable*	0	0	3	0	0
Unidentifiable**	0	0	0	3	1

* Probably *Dorosoma cepedianum*, Cypinidae, or Catostomidae.
** Probably *Dorosoma cepedianum* or Cypinidae.

Table 7. Analysis of ichthyoplankton entrainment samples (number/m^3) collected at the Alma Generating Station (Units 1-5), for Dairyland Power Cooperative in Pool 5 of the upper Mississippi River, March 1975-March 1976.

Species	May					June							July	August
	16	20	23	28	30	3	6	12	17	20	24	26	31	8
Clupeidae														
Dorosoma cepedianum	0	0	0	0	0	0	0	5	1	0	0	0	0	0
Esocidae														
Esox lucius	0	0	0	0	0	0	5	0	0	0	0	3	0	0
Cyprinidae														
Cyprinus carpio	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Notropis atherinoides	0	0	0	0	0	0	0	0	0	0	1	4	3	0
Unidentified minnows	0	3	6	2	11	5	32	7	5	3	0	1	0	0
Ictaluridae														
Noturus gyrinus	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Percichthyidae														
Morone chrysops	0	1	2	22	23	19	14	31	1	2	0	5	0	0
Centrarchidae														
Unidentified sunfish	0	0	0	0	0	1	8	0	0	0	0	2	0	0
Sciaenidae														
Aplodinotus grunniens	0	1	0	2	1	2	3	7	5	1	3	1	1	1
Unidentified - larvae	1	0	0	0	5	0	8	2	0	0	0	1	0	0
- eggs	0	0	1	0	0	0	0	0	0	0	0	0	0	0

Table 8. Densities of fish larvae/100 m^3 collected during daytime sampling periods (stations combined) in Pool 7 of the upper Mississippi River, 1981. (t means <0.4/100m^3.) Numbers in parentheses are water temperature (°C).

Species	April		May		June		July		August
	6 (8)	21 (9)	8 (14)	19 (16)	12 (22)	26 (25)	10 (27)	27 (23)	17 (23)
Clupeidae									
Dorosoma cepedianum	0.0	0.0	0.0	t	4.0	2.8	4.0	0.0	0.0
Hiodontidae									
Hiodon tergisus	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0
Cyprinidae									
Cyprinus carpio	0.0	0.0	t	0.0	5.2	2.4	4.0	t	0.0
Unidentified minnows	0.0	0.0	0.0	t	t	14.4	0.8	t	t
Catostomidae									
Ictiobus spp.	0.0	0.0	0.0	0.0	t	0.0	t	0.0	0.0
Moxostoma spp.	0.0	0.0	0.0	0.0	0.0	0.0	t	0.0	0.0
Unidentified catostomids	0.0	0.0	0.4	2.4	0.0	0.0	0.0	0.0	0.0
Atherinidae									
Labidesthes sicculus	0.0	0.0	0.0	0.0	t	t	t	0.0	0.0
Percichthyidae									
Morone chrysops	0.0	0.0	0.0	8.0	0.0	t	t	0.0	0.0
Centrarchidae									
Lepomis spp.	0.0	0.0	0.0	0.0	2.8	t	0.8	0.0	0.0
Pomoxis spp.	0.0	0.0	0.4	8.8	t	0.0	0.0	0.0	0.0
Percidae									
Perca flavescens	0.0	2.0	3.6	0.8	0.0	0.0	0.0	0.0	0.0
Percina caprodes	0.0	0.0	0.0	0.0	t	0.0	0.0	0.0	0.0
Stizostedion sp.	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0
Sciaenidae									
Aplodinotus grunniens	0.0	0.0	0.0	0.0	26.0	1.6	2.0	t	0.0

a

b

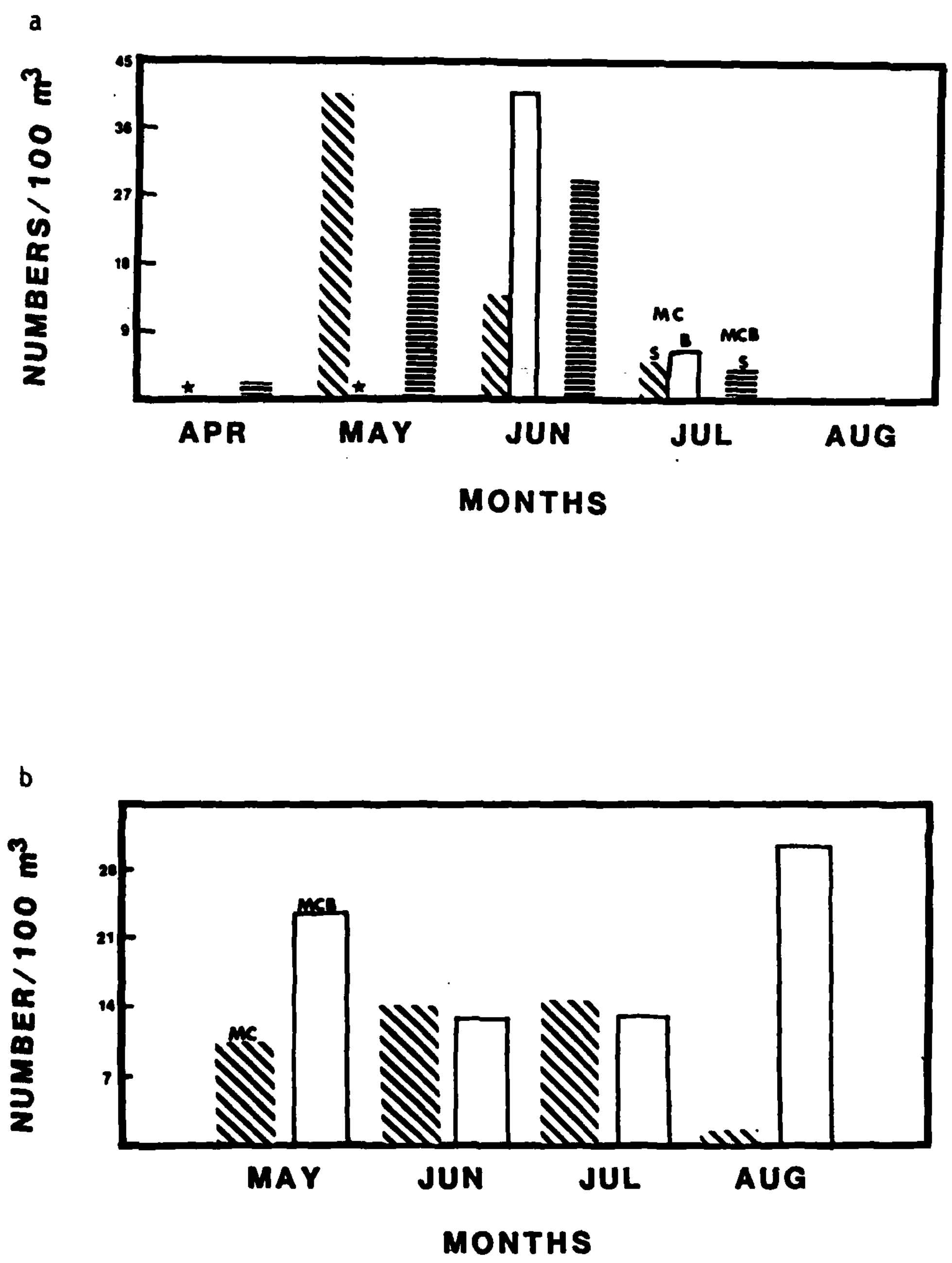

Fig. 4. Ichthyoplankton drift by month and habitat (a) Pool 7, 1981, and (b) Pool 8, 1982; MC = main channel (S = surface sample, B = bottom sample); MCB = main channel border (S = surface sample).
* = no fish larvae were collected.

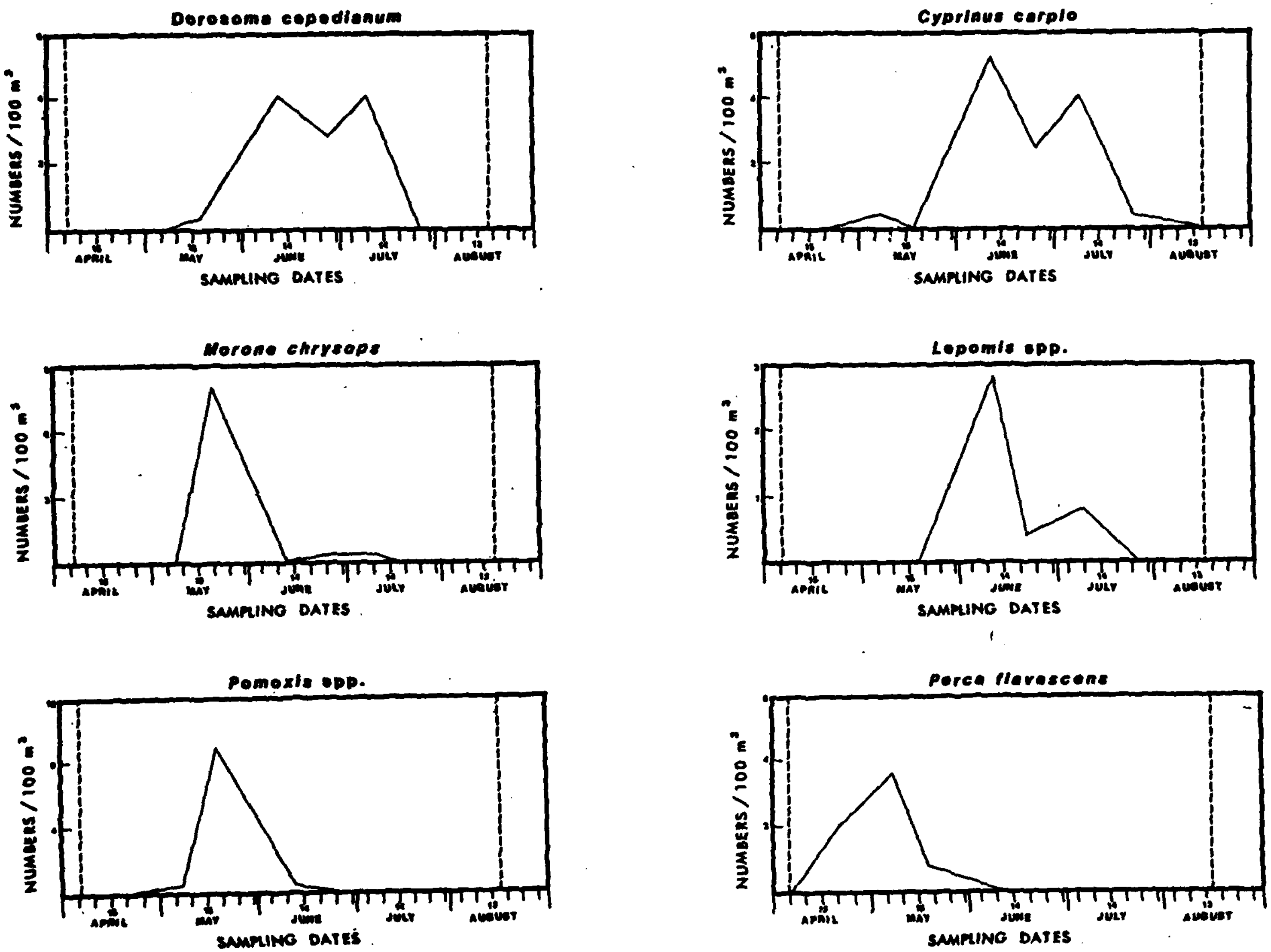

Fig. 5. Seasonal distribution of larval drift of selected species in Pool 7, 1981; main channel (surface and bottom samples), main channel border (surface samples), and backwater (surface samples) areas combined.

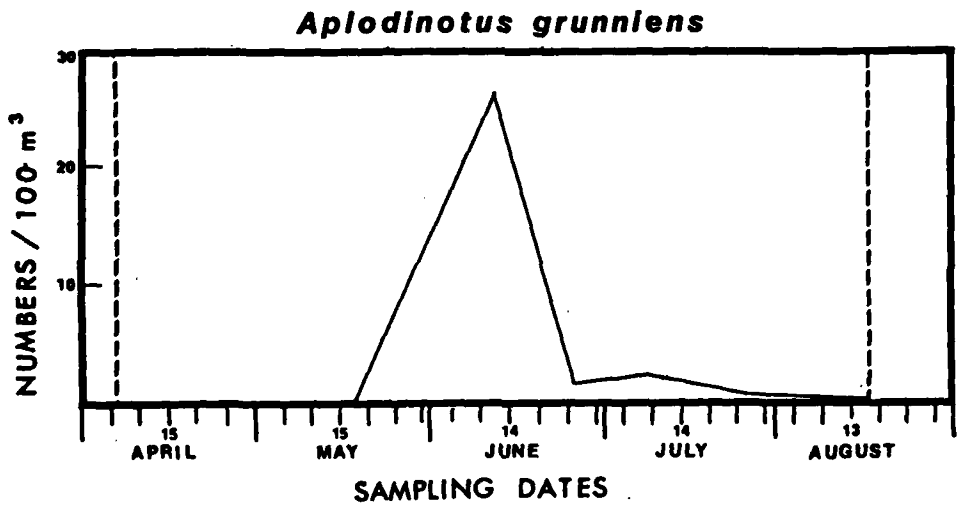

Fig. 5. Continued.

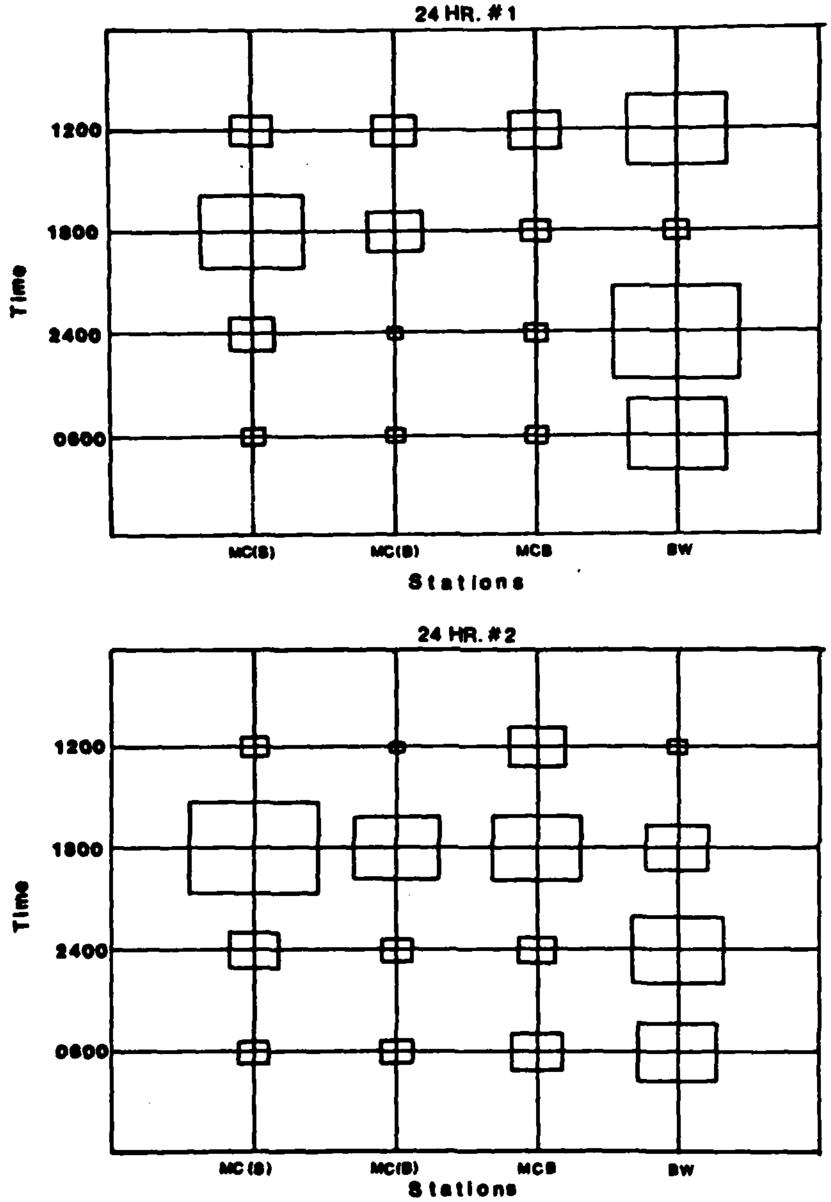

Fig. 6. Comparative distribution of ichthyoplankton by station and time during two 24-hour studies (24-hour #1, May 1981; 24-hour #2, June 1981), Pool 7, upper Mississippi River. Boxes represent comparative relative abundances (number/100 m^3). MC(S) and MC(B) = main channel surface and bottom, respectively; MCB = main channel border; BW = backwater.

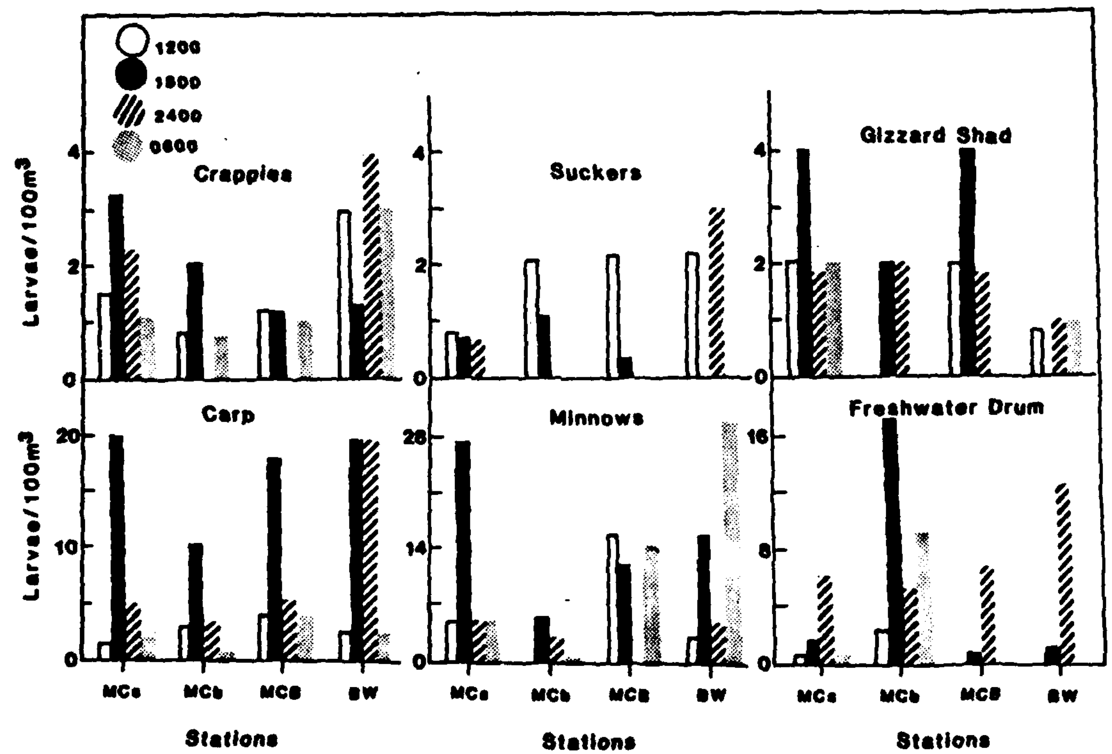

Fig. 7. Relative abundance (number/100 m^3) of selected species of ichthyoplankton during 24 hours by time and station, Pool 7, Mississippi River. MCs and MCb = main channel surface and bottom, respectively; MCB = main channel border; BW = backwater.

Table 9. Densities of fish larvae/100 m^3 collected (surface and bottom samples combined) during daytime sampling periods in main channel areas in Pool 8 of the upper Mississippi River, 1982. Numbers in parentheses are water temperature (°C).

Species	May				June					July				August
	5 (15)	12 (17)	20 (20)	26 (18)	2 (18)	9 (20)	17 (20)	22 (19)	30 (23)	6 (25)	13 (25)	20 (26)	28 (26)	5 (27)
Clupeidae														
Dorosoma cepedianum	0	0	6	22	52	6	30	8	0	0	8	0	0	0
Cyprinidae														
Cyprinus carpio	0	0	2	0	0	2	0	4	0	4	18	0	2	0
Notropis spp.	0	0	0	0	0	0	0	0	0	18	0	6	10	0
N. crysoleucas	0	0	2	0	0	0	0	0	0	0	0	0	0	0
N. atherinoides	0	0	0	0	0	4	0	0	0	0	0	0	0	0
Catostomidae														
Carpiodes spp.	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Ictiobus spp.	0	4	6	10	0	0	0	0	0	0	0	0	0	0
Unidentified catostomids	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Percichthyidae														
Morone chrysops	0	16	44	8	32	2	0	0	0	16	0	0	0	0
Centrarchidae														
Lepomis spp.	0	0	0	0	0	10	0	2	0	8	0	26	0	0
Pomoxis spp.	0	2	2	6	4	0	0	0	0	0	0	0	0	0
Percidae														
Perca flavescens	22	8	0	0	0	0	0	0	0	0	0	0	0	0
Sciaenidae														
Aplodinotus grunniens - larvae	0	0	0	24	0	6	10	2	68	82	0	0	0	0
- eggs	0	0	0	0	2	0	44	0	0	104	0	0	0	0
Unidentified	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 10. Densities of fish larvae/100 m^3 collected (surface samples) during daytime sampling periods in main channel border areas in Pool 8 of the upper Mississippi River, 1982. Numbers in parentheses are water temperature (°C).

Species	May				June					July				August
	5 (16)	12 (17)	20 (20)	26 (19)	2 (18)	9 (20)	17 (20)	22 (20)	30 (23)	6 (25)	13 (25)	20 (26)	28 (26)	5 (26)
Clupeidae														
Dorosoma cepedianum	0	0	9	32	64	5	53	6	8	0	0	0	0	0
Cyprinidae														
Cyprinus carpio	0	1	5	5	2	2	1	0	2	0	3	0	0	0
Notropis spp.	0	0	0	0	0	0	0	0	0	11	4	9	14	45
N. crysoleucas	0	0	1	0	0	0	0	0	0	0	0	0	0	0
N. atherinoides	0	0	0	0	0	10	0	0	0	0	0	0	0	0
Unidentified cyprinids	0	0	1	6	0	0	0	0	0	0	0	0	0	0
Catostomidae														
Carpiodes spp.	2	0	36	0	3	0	0	0	0	0	0	0	0	0
Ictiobus spp.	0	2	1	0	0	0	0	0	0	0	0	0	0	0
Moxostoma spp.	1	0	0	0	0	0	0	0	1	0	0	0	0	0
Unidentified catostomids	0	0	2	3	0	0	0	0	0	0	0	0	0	0
Percichthyidae														
Morone chrysops	0	20	156	21	12	0	0	0	0	0	0	0	0	0
Centrarchidae														
*Micropterus salmoides**	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepomis spp.	0	0	0	0	0	4	1	2	1	18	10	2	0	2
Pomoxis spp.	0	2	10	1	1	2	1	0	2	0	0	0	0	0
Percidae														
Perca flavescens	25	8	0	1	1	0	0	0	0	0	0	0	0	0
Stizostedion vitreum	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Etheostoma spp.	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Unidentified percids	0	4	2	1	0	0	0	0	0	0	0	0	0	0
Sciaenidae														
Aplodinotus grunniens - larvae	0	0	0	28	4	7	11	3	110	20	0	0	0	0
- eggs	0	0	23	0	0	0	35	0	0	174	0	0	0	0
Unidentified	0	0	0	0	1	0	0	1	0	0	0	0	0	0

* Not found in main channel border areas, but were collected in backwater areas.

Table 11. Densities of fish larvae/100 m^3 collected (surface samples) during daytime sampling periods in backwater areas in Pool 8 of the upper Mississippi River, 1982. Numbers in parentheses are water temperature (°C).

Species	May				June					July				August
	5 (16)	12 (18)	20 (19)	26 (18)	2 (19)	9 (21)	17 (21)	22 (20)	30 (23)	6 (25)	13 (25)	20 (27)	28 (26)	5 (25)
Lepisosteidae	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Clupeidae														
Dorosoma cepedianum	0	0	8	2	19	6	256	114	662	404	5	2	0	0
Esocidae														
Esox lucius	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Cyprinidae														
Cyprinus carpio	0	51	1	0	0	0	0	1	0	0	18	1	0	0
Notropis spp.	0	0	0	13	0	0	0	0	16	63	361	27	43	45
N. crysoleucas	0	0	0	0	0	0	0	27	0	2	0	0	0	0
N. atherinoides	0	0	0	0	0	7	34	8	0	0	85	0	0	0
Unidentified cyprinids	0	0	0	0	3	0	0	0	0	0	0	0	0	0
Catostomidae														
Carpiodes spp.*	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ictiobus spp.	0	156	4	2	0	0	0	0	0	0	0	0	0	0
Moxostoma spp.**	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified catostomids	0	0	0	0	0	0	0	4	0	0	0	0	0	0
Atherinidae														
Labidesthes sicculus	0	0	0	0	0	0	0	0	0	81	0	0	0	1
Percichthyidae														
Morone chrysops	0	3	14	10	1	0	2	1	3	0	0	0	0	0
Centrarchidae														
Micropterus salmoides	0	0	1	0	0	0	0	2	0	2	0	0	0	0
Lepomis spp.	0	1	0	0	0	25	10	27	25	289	572	6	5	0
Pomoxis spp.	0	59	36	27	7	1	0	7	3	10	0	0	0	0
Unidentified centrachids	0	0	5	0	0	0	0	0	0	0	0	0	0	0
Percidae														
Perca flavescens	154	45	4	0	1	0	2	1	3	0	0	10	0	0
*Stizostedion vitreum***	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Etheostoma spp.	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Unidentified percids	0	0	0	10	0	0	0	3	0	0	0	0	0	0
Sciaenidae														
Aplodinotus grunniens - larvae	0	0	0	3	1	0	12	1	22	3	2	0	0	0
- eggs	0	0	0	0	0	0	6	1	143	0	0	0	0	0
Unidentified	0	0	0	0	1	0	0	0	0	0	0	0	0	0

* Not found in backwater ares, but weere collected in mail channel and main channel border areas.

** Not found in backwater areas, but were collected in main channel border areas.

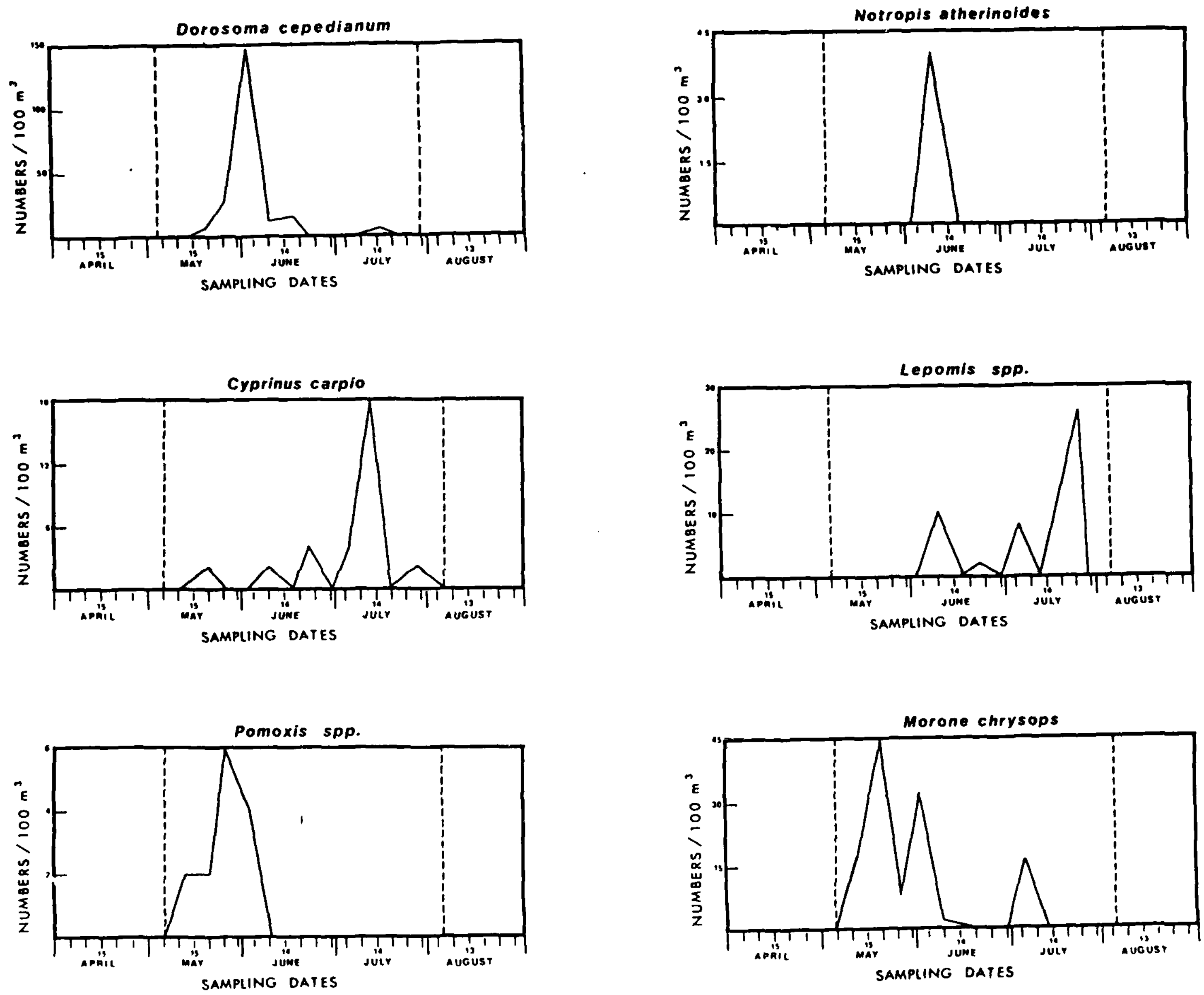

Fig. 8. Seasonal distribution of larval drift of selected species in Pool 8 (main channel surface and bottom), 1982.

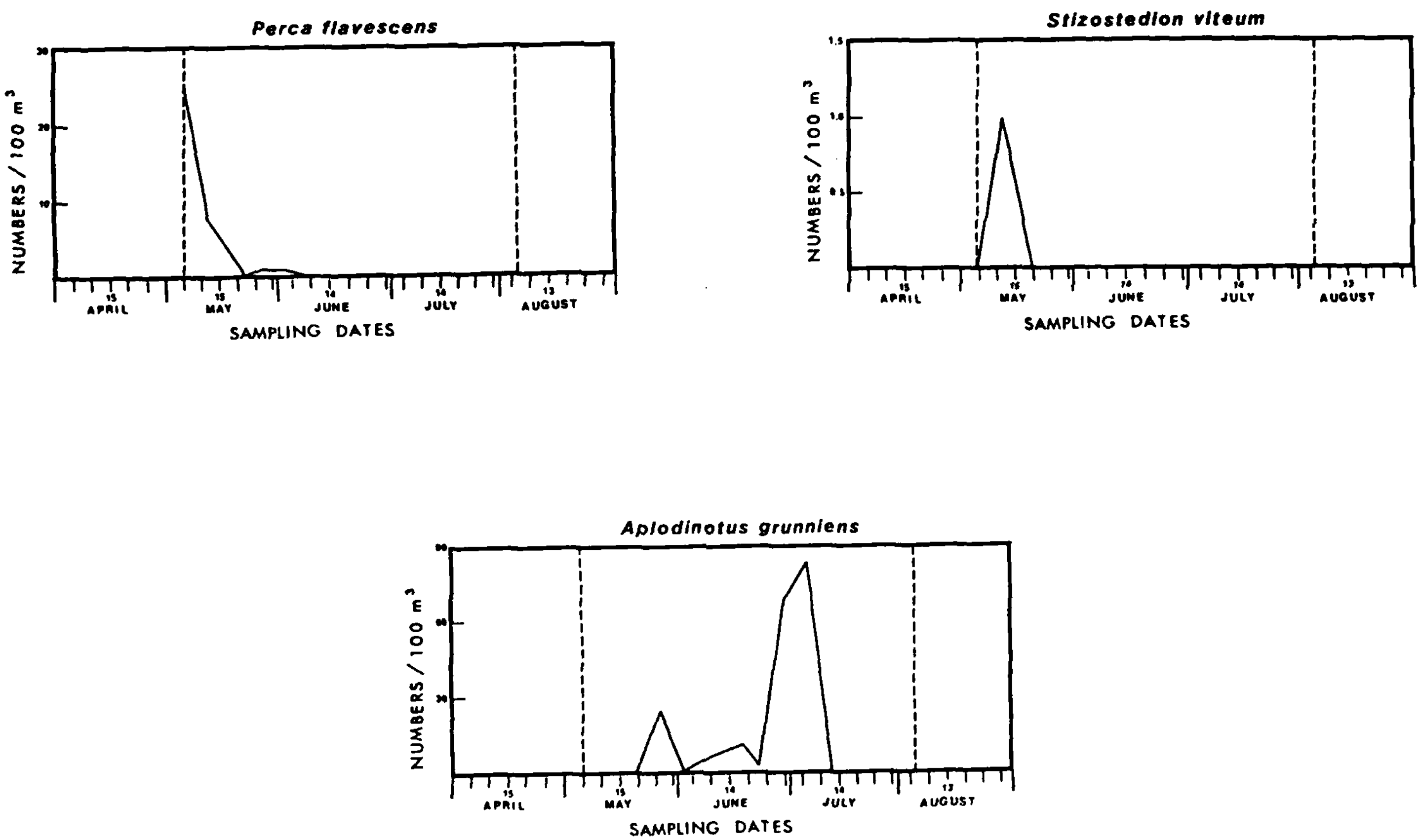

Fig. 8. Continued.

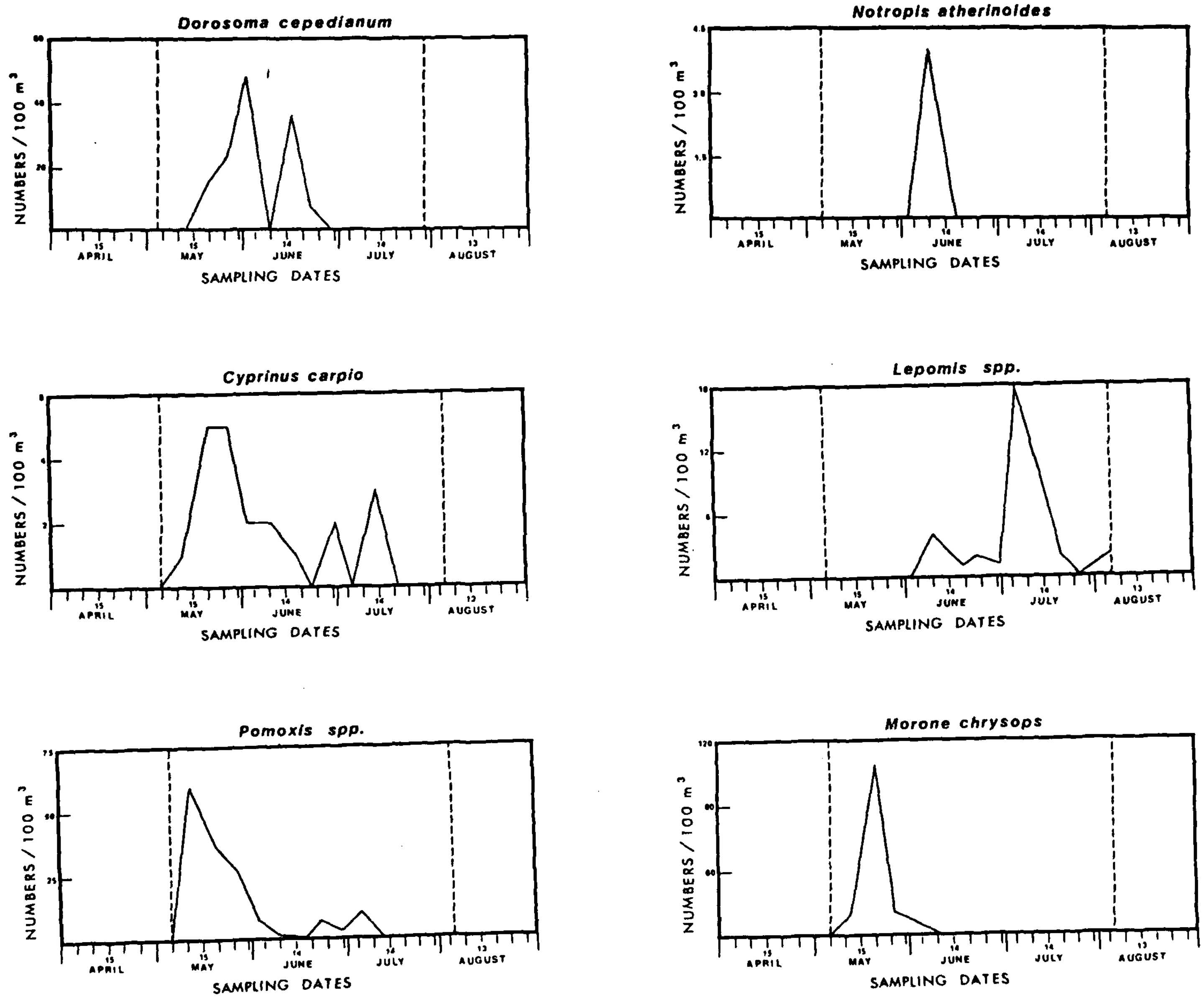

Fig. 9. Seasonal distribution of larval drift of selected species in Pool 8 (main channel border surface samples), 1982.

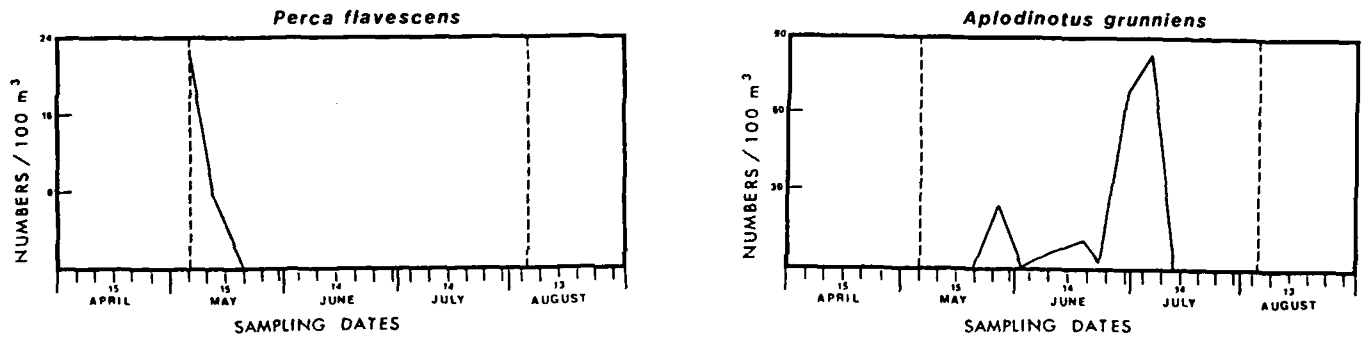

Fig. 9. Continued.

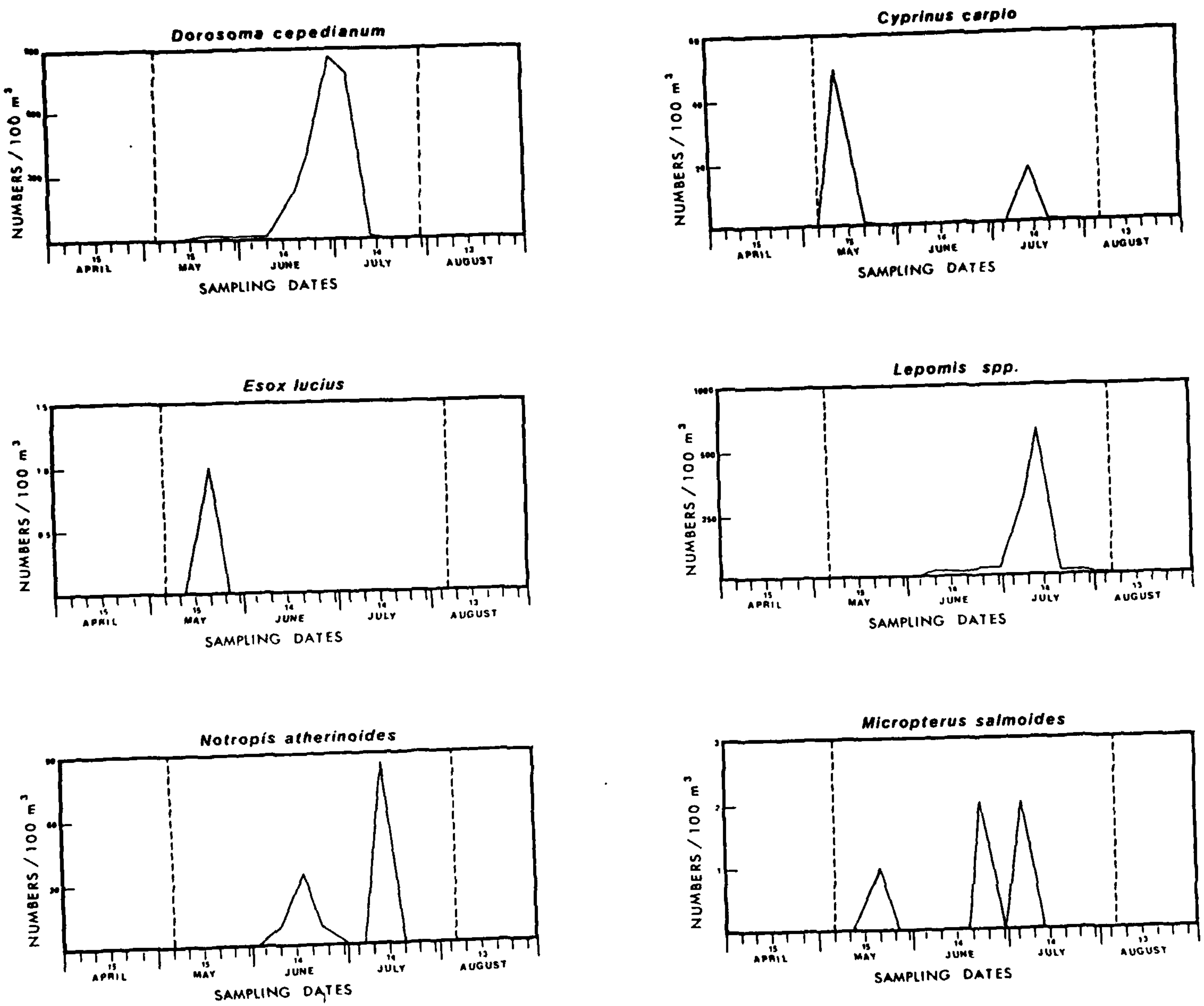

Fig. 10. Seasonal distributon of larval drift of selected species in Pool 8 (backwater surface samples), 1982.

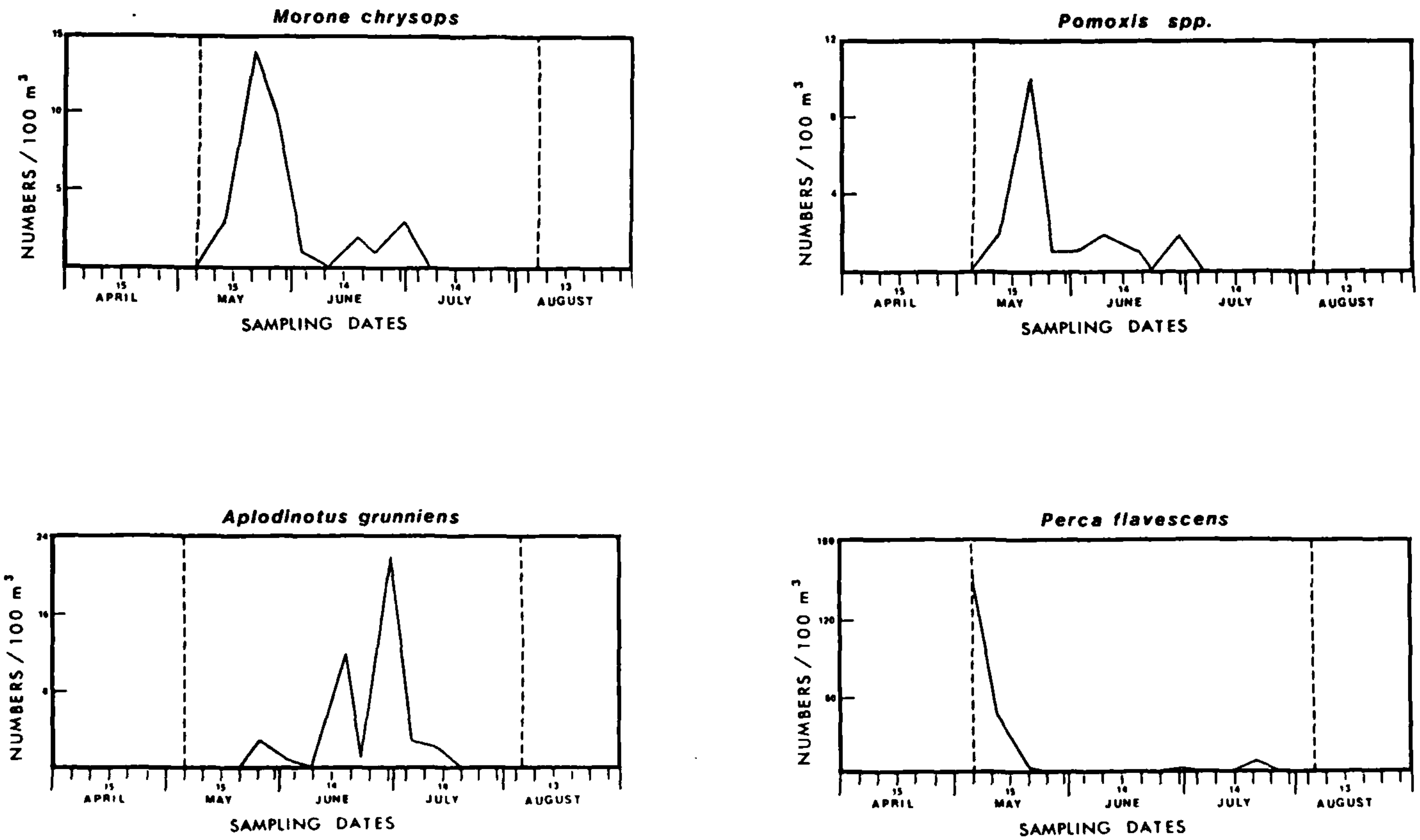

Fig. 10. Continued.

Table 12. Larval fish collected (number/100 m^3) at the west shore (main channel border) adjacent to Dairyland Power Cooperative's Genoa site in Pool 9 of the upper Mississippi River, 1980.

Species	May 21	June 3	June 10	June 19	June 25 1700 h	June 25 1200 h	June 25 0800 h
Cyprinidae	0	2.8	7.4	0.9	29.8	29.0	5.1
Catostomidae	0	0	0	0	0	0	0
Sciaenidae *Aplodinotus grunniens*	0	0	0	0	25.5	0	2.6

Table 13. Larval fish collected (number/100 m^3) near black buoy (main channel), adjacent to Dairyland Power Cooperative's Genoa site in Pool 9 of the upper Mississippi River, 1980.

Species	May 21	June 3	June 10	June 19	June 25 1700 h	June 25 1200 h	June 25 0800 h
Cyprinidae	0	1.5	4.6	0	309.1	594.6	55.3
Catostomidae	0	0	0	0	0	0	0
Sciaenidae *Aplodinotus grunniens*	0	0	0	0	42.0	81.1	57.4

Table 14. Larval fish collected (number/100 m^3) near red buoy (main channel), adjacent to Dairyland Power Cooperative's Genoa site in Pool 9 of the upper Mississippi River, 1980.

Species	May 21	June 3	June 10	June 19	June 25 1700 h	June 25 1200 h	June 25 0800 h
Cyprinidae	0	0	0	0	119.9	670.6	66.9
Catostomidae	0	0	0	0	0	0	0
Sciaenidae *Aplodinotus grunniens*	0	0	0	0	5.1	9.3	13.4

Table 15. Larval fish collected (number/100 m^3) at the east shore (main channel border) adjacent to Dairyland Power Cooperative's Genoa site in Pool 9 of the upper Mississippi River, 1980.

Species	May 21	June 3	June 10	June 19	June 25 1700 h	June 25 1200 h	June 25 0800 h
Cyprinidae	0	0	3.7	0	0.9	81.5	28.9
Catostomidae	0	51.6	1.2	0	0	0	0
Sciaenidae *Aplodinotus grunniens*	0	0	0	0	0	28.9	150.1

Table 16. Larval fish collected in grab samples from the east shore (ES) and west shore (WS) main channel border sites adjacent to Dairyland Power Cooperative's Genoa Generating Station in Pool 9 of the upper Mississippi River, 1979 and 1980.

	June 1979	May	June				
	18	20	3		10		19
Species	ES	ES	WS	ES	WS	ES	ES
Lepisosteidae *Lepisosteus* sp.	0	0	1	0	0	0	0
Catostomidae	11	7	0	105	25	27	4
Centrachidae *Pomoxis* sp.	0	0	0	1	0	0	0

Table 17. Estimated total entrainment of fish larvae and eggs at Dairyland Power Cooperative's G-3 Station in Pool 9 of the upper Mississippi River near Genoa, Wisconsin, 1979 and 1980.

Taxa	1979	1980
Clupeidae		
Dorosoma sp.	2×10^5	3×10^4
Hiodontidae		
Hiodon sp.	8×10^4	0
Cyprinidae	3×10^5	7×10^5*
Catostomidae	3×10^5	8×10^4
Percichthyidae		
Morone sp.	1×10^6	6×10^5*
Centrarchidae		
Pomoxis sp.	2×10^5	0
Percidae		
Stizostedion sp.	0	5×10^5
Sciaenidae		
Aplodinotus grunniens	5×10^6	2×10^5*
Total larval fish	9×10^6	2×10^6*
Total eggs	0	0

* Evidence was found that entrainment of these taxa probably occurred after 30 June 1980 when sampling was curtailed, therefore estimates were probably lower than expected for the year.

Table 18. Analysis of egg and fry entrainment samples collected at Genoa, Wisconsin, for Dairyland Power Cooperative in Pool 9 of the upper Mississippi River, 1975.

Species	May	June	
	21	4	11
Clupeidae			
Dorosoma cepedianum	0	0	2
Esocidae			
Esox lucius	0	1	0
Cyprinidae			
Unidentified minnows	0	0	5
Catostomidae			
Unidentified suckers	1	0	0
Percichthyidae			
Morone chrysops	1	32	127

Table 19. Analysis of ichthyoplankton entrainment samples collected at the Stoneman Generating Station, for Dairyland Power Cooperative in Pool 11 of the upper Mississippi River, April 1975-April 1976.

	April	June					July				August	
Species	26	2	9	16	23	30	8	15	21	28	19	25
Lepisosteidae												
Lepisosteus platostomus	0	0	0	0	0	0	1	0	0	0	0	0
Hiodontidae												
Hiodon tergisus	2	6	1	0	0	0	0	0	0	0	0	0
Cyprinidae												
Hybopsis storeriana	0	0	0	0	0	0	0	0	0	3	0	0
Notropis spp.	0	0	9	2	7	2	1	1	0	0	0	5
Notropis atherinoides	0	0	0	0	0	0	0	0	2	2	0	0
Notropis hudsonius	0	0	0	0	0	1	0	0	0	0	0	0
Catostomidae												
Ictiobus bubalus	0	0	0	0	0	0	0	1	0	0	0	0
Ictiobus cyprinellus	0	0	0	2	2	2	0	0	0	0	0	0
Unidentified minnows	13	0	0	0	0	0	0	0	0	0	0	0
Ictaluridae												
Ictalurus melas	0	0	0	0	0	0	1	0	0	0	0	0
Ictalurus natalis	0	0	0	0	0	0	0	0	0	1	0	0
Ictalurus punctatus	0	0	0	0	0	0	1	2	0	0	0	0
Percichthyidae												
Morone chrysops	36	135	131	122	33	5	0	0	0	0	0	0
Centrarchidae												
Micropterus salmoides	0	0	0	0	0	1	0	0	0	0	0	0
Lepomis macrochirus	0	0	0	0	0	0	0	0	1	1	0	0
Percidae												
Etheostoma nigrum	0	0	0	0	0	1	0	0	0	0	0	0
Percina caprodes	0	0	0	1	0	0	0	0	0	0	0	0
Stizostedion spp.	2	5	4	2	0	0	0	0	0	0	0	0
Unidentified perch	0	0	0	0	1	0	0	0	0	0	0	0
Sciaenidae												
Aplodinotus grunniens	0	0	8	24	2	3	8	2	0	0	10	4
Unidentified - larvae	0	0	2	1	1	0	0	0	2	2	0	0

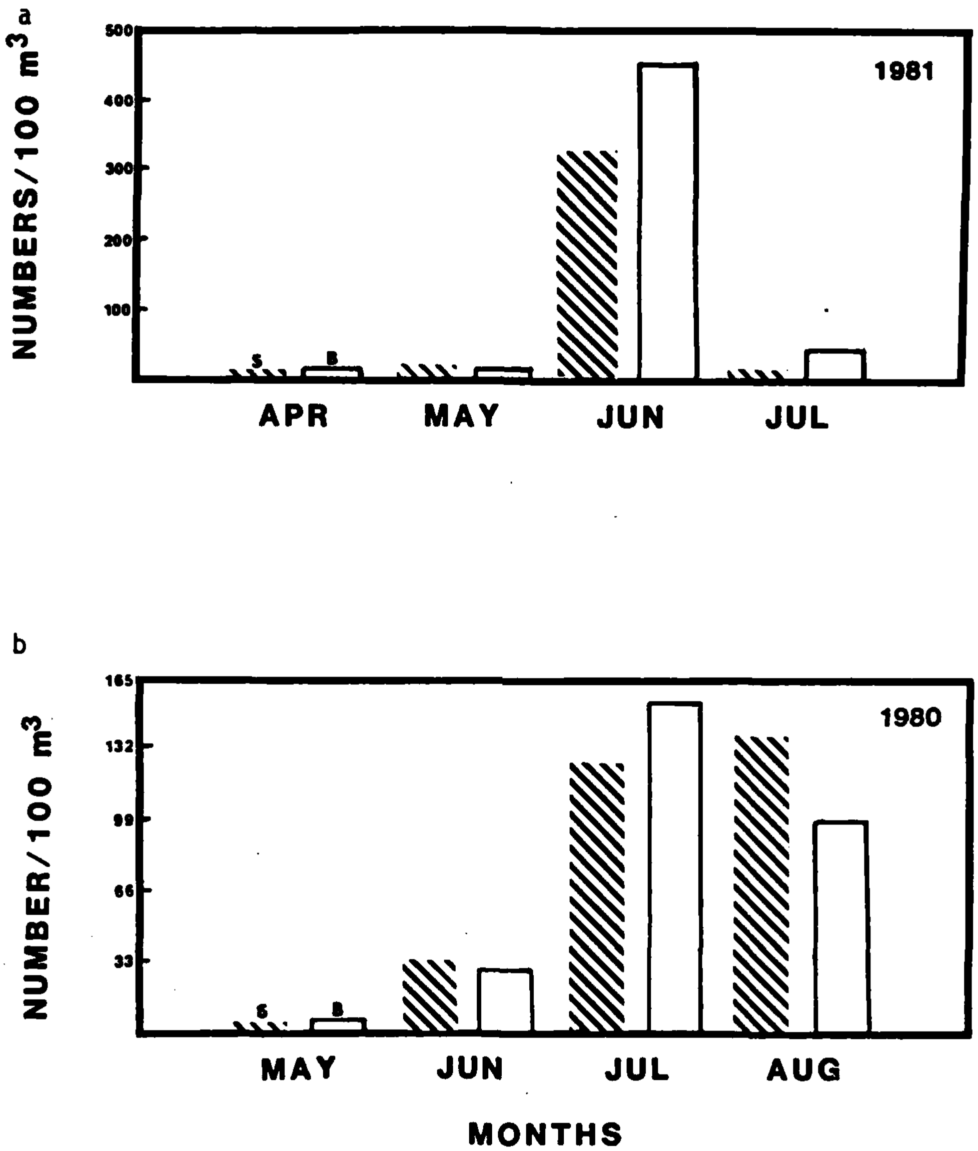

Fig. 11. Ichthyoplankton drift by month and habitat in Pool 14 (a) 1981 and (b) 1980. S = surface; B = bottom.

Table 20. Densities of fish larvae/100 m^3 collected in the main channel (surface and bottom combined) of Pool 14 of the upper Mississippi River near the Quad-Cities Station, 1981. Numbers in parentheses are water temperatures (°C).

Species	April			May				June					July			
	16 (12)	21 (12)	28 (14)	5 (15)	12 (13)	19 (14)	26 (20)	2 (22)	9 (23)	16 (24)	23 (22)	30 (24)	7 (27)	14 (28)	21 (26)	28 (21)
Clupeidae																
Dorosoma cepedianum	0.0	0.0	0.0	0.0	0.5	0.0	15.2	48.0	202.2	54.8	26.0	3.1	1.1	0.0	0.0	0.0
Hiodontidae																
Hiodon tergisus	0.0	0.0	0.0	2.0	1.7	0.7	0.0	0.5	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0
Cyprinidae																
Cyprinus carpio	0.0	0.0	0.0	0.0	2.1	1.9	0.0	166.4	27.8	124.0	115.3	22.1	12.2	6.5	0.0	0.0
Notropis atherinoides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	31.0	1.4	1.5	3.2	2.1	1.1	0.0	4.0
Pimephales spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0
Unidentified cyprinids	0.0	0.0	0.0	0.0	0.0	0.6	0.0	2.2	2.5	0.0	2.5	12.4	2.3	4.8	0.6	3.0
Catostomidae																
Ictiobinae	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Carpiodes spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.5	0.0	1.8	5.6	9.4	0.7	0.0
C. cyprinus	0.0	0.0	0.0	0.0	0.6	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ictiobus spp.	0.0	0.0	0.0	6.7	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
I. bubalus	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ictaluridae																
Ictalurus punctatus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	3.8	0.0	0.0	0.0	0.0
Percichthyidae																
Morone chrysops	0.0	0.0	0.0	0.0	0.0	0.0	0.6	7.2	8.0	2.3	2.6	0.0	0.0	0.0	0.0	0.0
Centrarchidae																
Lepomis macrochirus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Pomoxis spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	2.0	0.0	0.6	0.0	0.0	0.0	0.0
Percidae																
Etheostoma spp.	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E. nigrum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Perca flavescens	1.5	7.4	9.5	7.3	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percina caprodes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stizostedion spp.	0.0	1.7	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sciaenidae																
Aplodinotus grunniens - larvae	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.7	396.1	447.2	128.3	26.9	6.7	29.6	1.3	2.4
- eggs	0.0	0.0	0.0	0.0	0.0	0.0	26.1	124.3	284.2	45.1	0.0	0.8	1.1	0.0	0.0	0.0
Unidentified - eggs	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

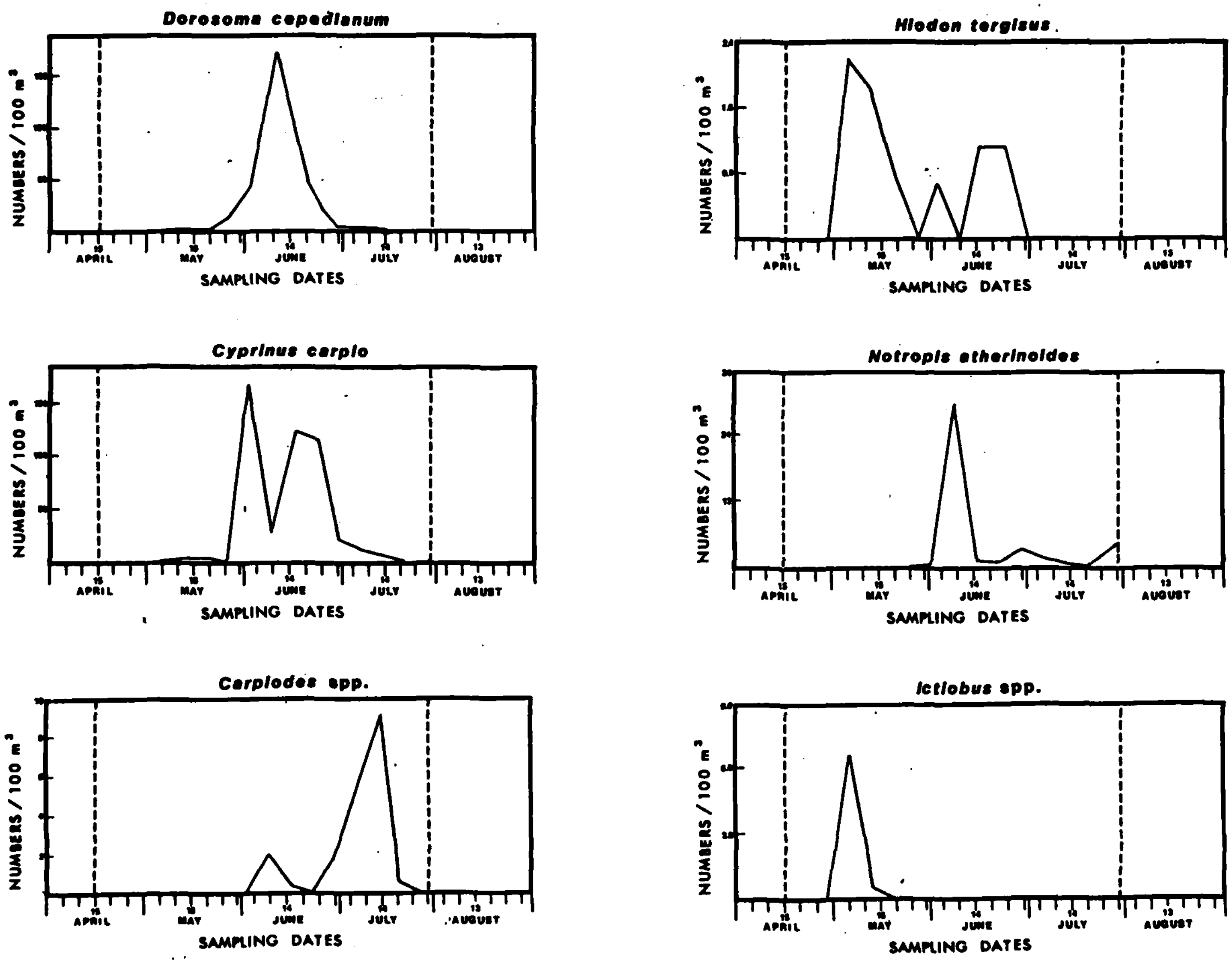

Fig. 12. Seasonal distribution of larval drift of selected species at a main channel border site (subsurface and bottom) in Pool 14, 1981.

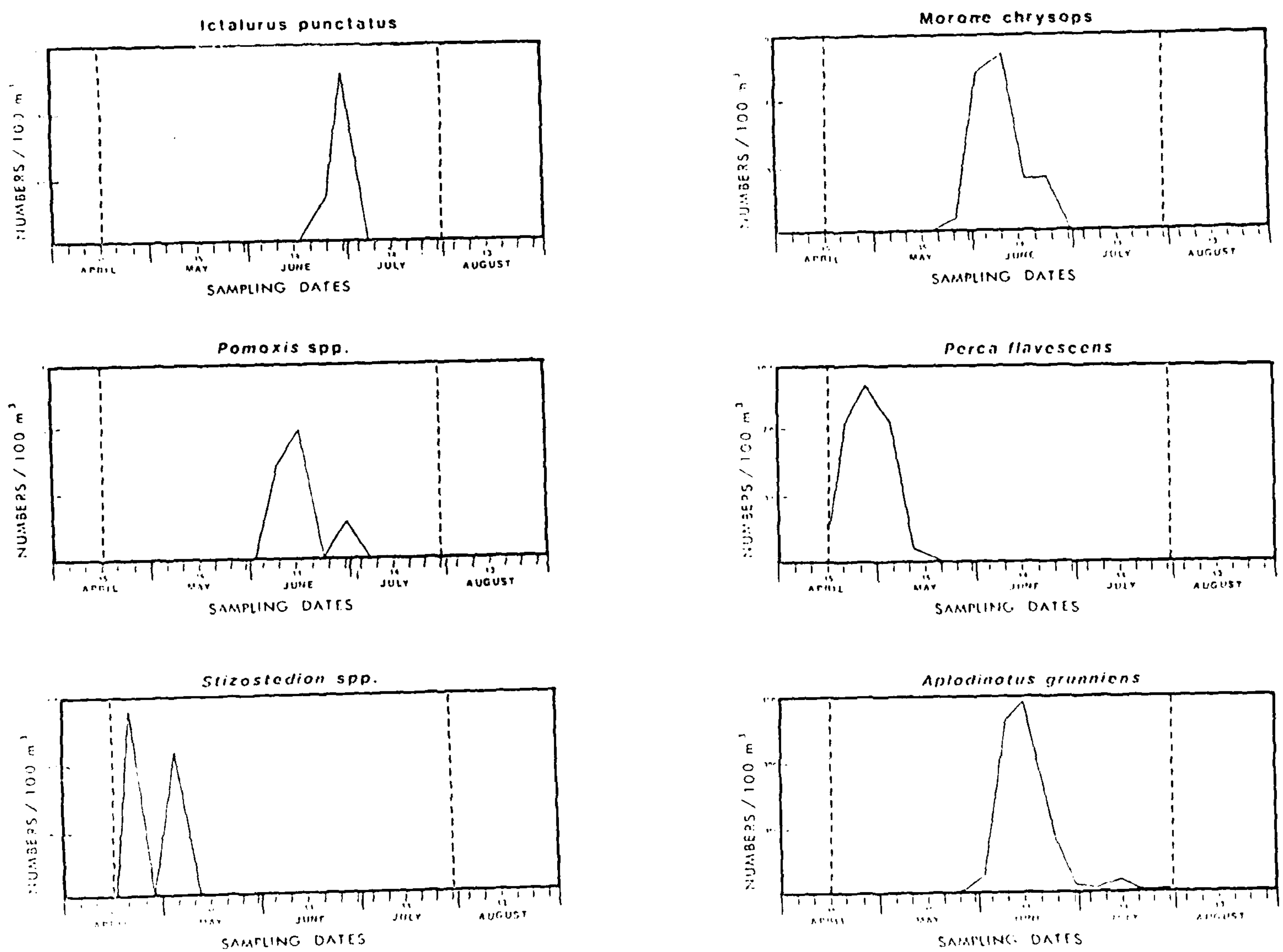

Fig. 12. Continued.

Table 21. Densities of fish eggs/100 m^3 collected at a main channel border site in Pool 14 of the upper Mississippi River near the Quad-Cities Station, 1981.

Species	April			May				June					July			
	16	21	28	5	12	19	26	2	9	16	23	30	7	14	21	28
AM																
Subsurface																
Notropis atherinoides	0	0	0	0	0	0	0	4.7	0	2.0	0	0	0	0	0	0
Aplodinotus grunniens	0	0	0	0	0	0	34.5	198.6	270.1	38.1	0	0	2.2	0	0	0
Unidentified	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bottom																
Notropis atherinoides	0	0	0	0	0	0	0	0	2.9	3.9	0	7.7	0	0	0	0
Aplodinotus grunniens	0	0	0	0	0	0	55.8	193.3	312.4	54.1	0	2.6	0	0	0	0
Unidentified	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PM																
Subsurface																
Notropis atherinoides	0	0	0	0	0	0	0	0	0	0	0	0	0	2.2	0	0
Aplodinotus grunniens	0	0	0	0	0	0	5.4	45.2	283.3	48.2	0	0	0	0	0	0
Unidentified	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bottom																
Notropis atherinoides	0	0	0	0	0	0	0	2.0	0	0	0	0	0	0	0	0
Aplodinotus grunniens	0	0	0	0	0	0	8.5	60.1	271.0	39.9	0	0	2.3	0	0	0
Unidentified	0	0	0	0	2.1	0	0	0	0	0	0	0	0	0	0	0

Table 22. Densities of fish larvae/100 m^3 (daily mean, subsurface and bottom tows) collected at Location 2 (main channel border) in Pool 14 of the upper Mississippi River near the Quad-Cities Station, 1980. Numbers in parentheses are water temperature (°C).

Species	April			May				June				July				
	15 -	22 -	29 -	6 (18)	13 (16)	20 (17)	27 (22)	3 (23)	10 (21)	17 (23)	24 (24)	1 (26)	8 (27)	15 (29	22 (28)	29 (26)
Clupeidae																
Dorosoma cepedianum	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	2.2	15.4	1.2	3.0	0.7	1.7	0.0	0.0
Hiodontidae																
Hiodon tergisus	0.0	0.0	0.0	1.3	4.1	1.2	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cyprinidae																
Cyprinus carpio	0.0	0.0	0.0	0.5	0.0	1.6	4.7	44.6	14.7	84.6	98.6	107.3	13.0	13.4	0.0	2.8
Notropis spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	1.2	2.8	0.0	0.0	0.5	1.2
Unidentified cyprinids	0.0	0.0	0.0	0.0	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0
Catostomidae																
Carpiodes spp.	0.0	0.0	0.0	8.1	25.9	2.8	0.5	0.0	0.6	8.4	4.1	4.3	0.0	0.0	0.0	0.0
Percichthyidae																
Morone chrysops	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Centrarchidae																
Lepomis spp.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7	0.6	6.0	0.0	0.0	0.0	0.0
Pomoxis spp.	0.0	0.0	0.0	0.0	0.0	0.6	0.0	1.8	0.0	2.7	1.2	0.0	0.0	0.0	0.0	0.0
Percidae																
Etheostoma spp.	0.0	0.0	0.5	0.0	3.2	0.6	0.0	0.0	0.6	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Perca flavescens	0.0	0.0	0.0	23.6	4.9	1.7	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percina caprodes	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stizostedion spp.	0.0	0.0	1.1	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified percids	0.0	0.0	1.6	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sciaenidae																
Aplodinotus grunniens - larvae	0.0	0.0	0.0	0.0	0.0	1.1	28.0	36.6	40.5	57.9	127.2	303.7	118.7	14.0	1.1	5.5
- eggs	0.0	0.0	0.0	0.0	0.0	17.5	68.0	18.6	0.5	59.7	5.3	1.2	20.0	19.2	1.7	2.4
Unidentified - larvae	0.0	0.0	0.0	0.6	0.0	1.7	0.0	0.0	0.6	2.4	0.6	0.0	1.3	0.5	0.0	0.0
- eggs	0.0	0.0	0.0	0.0	0.0	2.9	2.1	3.1	0.0	3.9	4.4	1.2	6.8	0.5	0.0	0.0
River discharge (m^3/sec)	2,458	2,404	1.438	1,152	719	702	816	1,291	1,954	2,917	1,303	997	680	680	850	680

Table 23. Densities of fish eggs/100 m³ collected in Pool 14 of the upper Mississippi River, main channel site (surface and bottom samples combined), near the Quad-Cities Station, 1980.

	April			May				June				July				
Species	15	22	29	6	13	20	27	3	10	17	24	1	8	15	22	29
Subsurface																
Aplodinotus grunniens	0	0	0	0	0	17.1	125.4	0	1.1	55.1	4.5	1.1	19.0	21.6	2.3	1.2
Unidentified	0	0	0	0	0	3.6	4.1	3.1	0	7.8	1.7	1.4	13.7	1.1	0	0
Bottom																
Aplodinotus grunniens	0	0	0	0	0	17.9	10.7	37.3	0	64.3	6.0	1.3	21.0	16.9	1.1	3.6
Unidentified	0	0	0	0	0	2.3	0	3.1	0	0	7.2	1.0	0	0	0	0

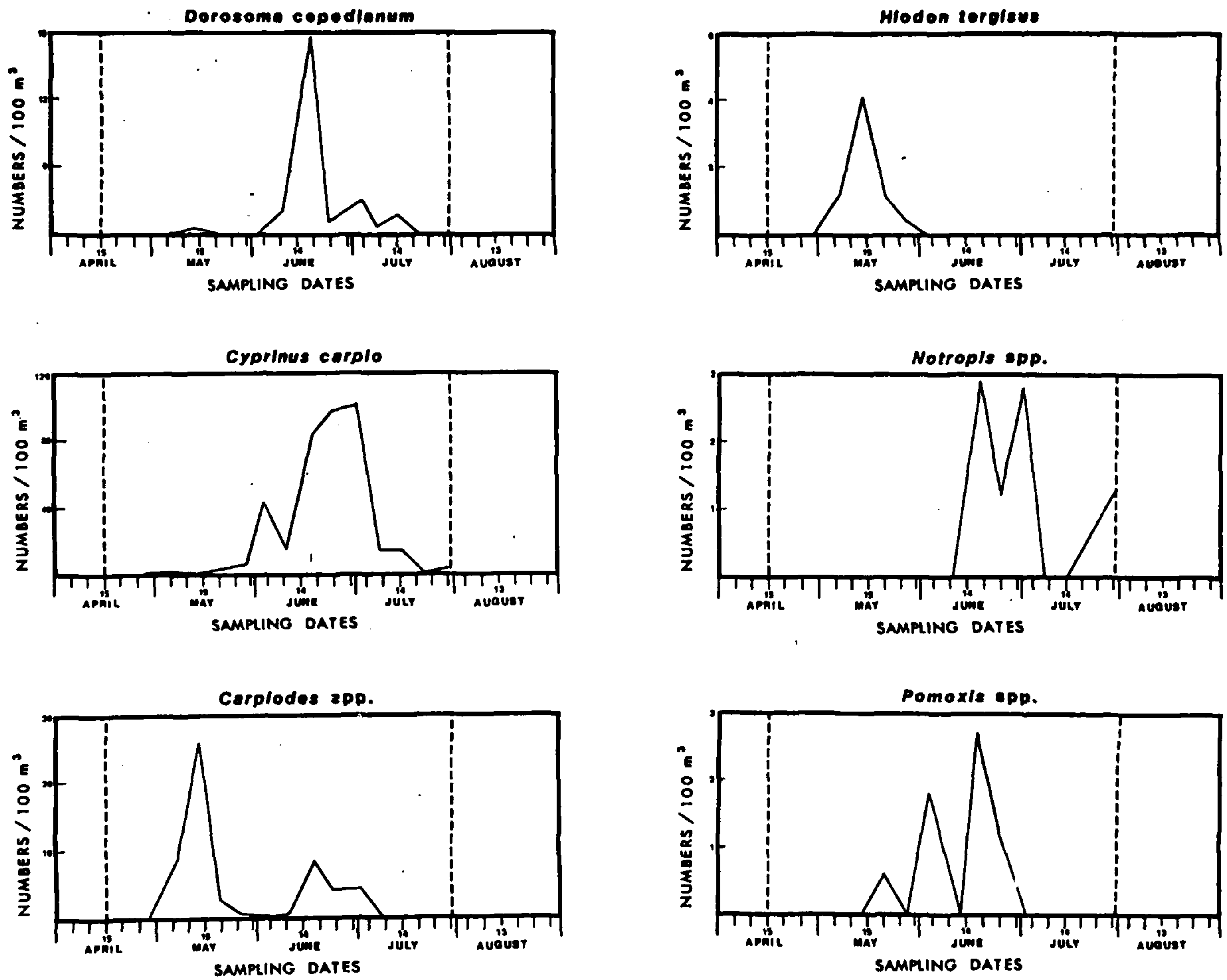

Fig. 13. Seasonal distribution of larval drift of selected species at a main channel border site (subsurface and bottom) in Pool 14, 1980.

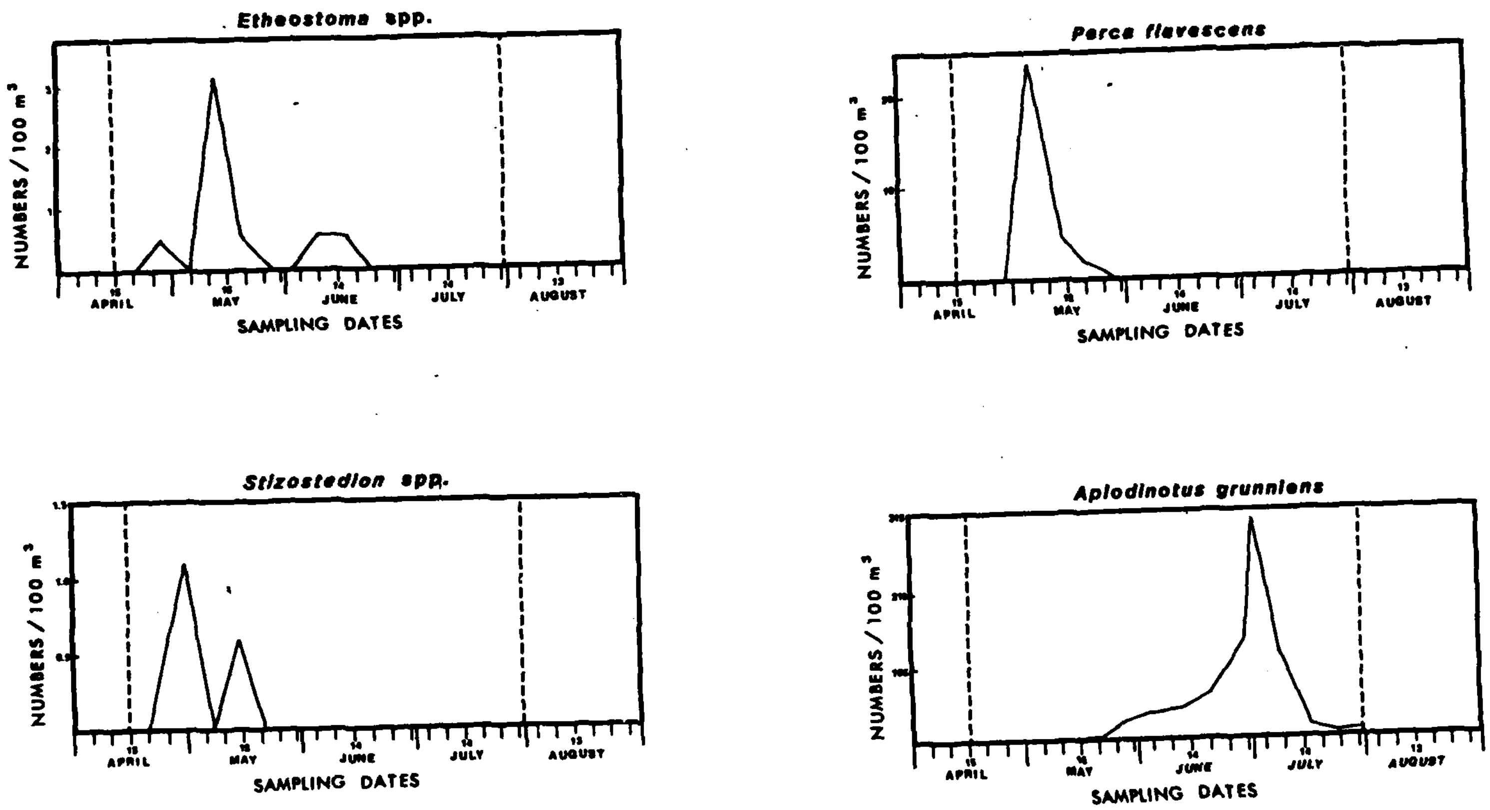

Fig. 13. Continued.

Table 24. Densities of fish larvae/100 m^3 (daily maxima, near-surface and bottom tows) collected at six sampling locations (main channel, main channel border, and backwater combined) in Pool 14 of the upper Mississippi River, 1979. Numbers in parentheses are water temperature (°C).

Species	April	May					June				July				
	25 (13)	1 (10)	8 (14)	15 (13)	22 (18)	30 (19)	5 (22)	11 (21)	19 (22)	26 (22)	5 (23)	12 (26)	17 (26)	25 (25)	31 (27)
Clupeidae															
Dorosoma cepedianum	0	0	0	0	5	3	24	18	54	12	10	6	0	0	3
Hiodontidae															
Hiodon tergisus	0	0	0	0	5	12	10	10	5	3	0	0	0	0	0
Cyprinidae															
Cyprinus carpio	0	0	0	38	97	27	34	156	135	49	102	36	8	14	0
Unidentified cyprinids	0	0	0	3	3	3	26	252	735	37	62	11	139	40	16
Catostomidae	0	0	0	39	124	9	8	16	12	18	8	5	3	7	3
Ictaluridae	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0
Percichthyidae															
Morone chrysops	0	0	0	5	10	3	17	32	20	11	8	0	0	0	0
Centrarchidae															
Lepomis spp.	0	0	0	0	0	0	0	21	10	8	5	13	22	6	9
Pomoxis spp.	0	0	0	8	53	11	15	24	7	0	0	0	0	0	0
Percidae															
Etheostoma spp.	0	0	0	3	3	5	3	3	0	3	0	0	0	0	0
Perca flavescens	3	3	10	36	21	3	5	3	3	0	0	0	0	0	0
Percina caprodes	0	0	0	5	5	3	3	3	0	0	0	0	0	0	0
Stizostedion spp.	0	0	0	7	6	0	0	0	0	0	0	0	0	0	0
Sciaenidae															
Aplodinotus grunniens - larvae	0.0	0.0	0.0	0.0	0.0	0.0	60.0	540.0	892.0	451.0	40.0	14.0	20.0	252.0	10.0
- eggs	0.0	0.0	0.0	0.1	8.7	5.0	22.0	15.0	4.4	0.4	0.2	1.1	2.1	2.2	1.3
Unidentified - eggs	0.0	0.0	0.0	0.0	0.1	0.9	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0

Table 25. Densities of fish eggs/100 m^3 collected at the main channel (MC) and main channel border (MCB) sites in Pool 14 of the upper Mississippi River near Quad-Cities Station, 1979.

	April		May					June				July				
Species	18	25	1	8	15	22	30	5	11	19	26	5	12	17	25	31
Location 2 (MCB)																
Subsurface																
percid	0	0	0	0	0	1.3	0	0	0	0	0	0	0	0	0	0
Aplodinotus grunniens	0	0	0	0	0	36.7	10.8	2.19	28.1	1.7	1.3	1.2	4.8	5.9	0	2.5
Unidentified	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bottom																
Aplodinotus grunniens	0	0	0	0	0	33.3	14.4	23.3	20.4	16.3	1.4	0	4.6	12.3	1.2	1.0
Unidentified	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Location 4 (MC)																
Subsurface																
Aplodinotus grunniens	0	0	0	0	0	11.2	6.9	23.3	7.2	2.5	0	1.0	0	0	0	1.2
Unidentified	0	0	0	0	0	0	0	0	1.5	0	0	0	0	0	0	0
Bottom																
Hiodon tergisus	0	0	0	0	1.3	0	0	0	0	0	0	0	0	0	0	0
Aplodinotus grunniens	0	0	0	0	0	10.4	4.6	16.6	19.7	1.2	1.3	0	0	0	1.3	1.2
Unidentified	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Location 6 (MCB)																
Subsurface																
Aplodinotus grunniens	0	0	0	0	0	2.5	3.1	4.9	0	1.2	0	0	0	1.2	0	1.4
Unidentified	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bottom																
Aplodinotus grunniens	0	0	0	0	0	4.8	1.3	3.5	7.8	2.5	0	0	1.3	1.2	19.2	5.7
Unidentified	0	0	0	0	0	0	0	0	0	1.3	0	0	0	0	0	1.2
River mile 514.1 (MC)																
Subsurface																
Aplodinotus grunniens	0	0	0	0	1.2	20.1	1.2	36.7	17.5	8.3	0	0	0	0	0	0
Unidentified	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bottom																
Aplodinotus grunniens	0	0	0	0	0	34.6	2.9	17.8	33.5	1.3	0	0	0	0	0	0
Unidentified	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
River mile 522.5 (MC)																
Subsurface																
Aplodinotus grunniens	0	0	0	0	0	1.2	4.2	39.3	11.2	5.1	0	0	0	0	0	0
Unidentified	0	0	0	0	0	0	0	5.2	0	0	0	0	0	0	0	0
Bottom																
Aplodinotus grunniens	0	0	0	0	0	2.1	0.9	52.0	4.2	3.9	0	0	0	0	0	0
Unidentified	0	0	0	0	0	1.2	0	4.1	0	1.2	1.3	0	0	0	0	0

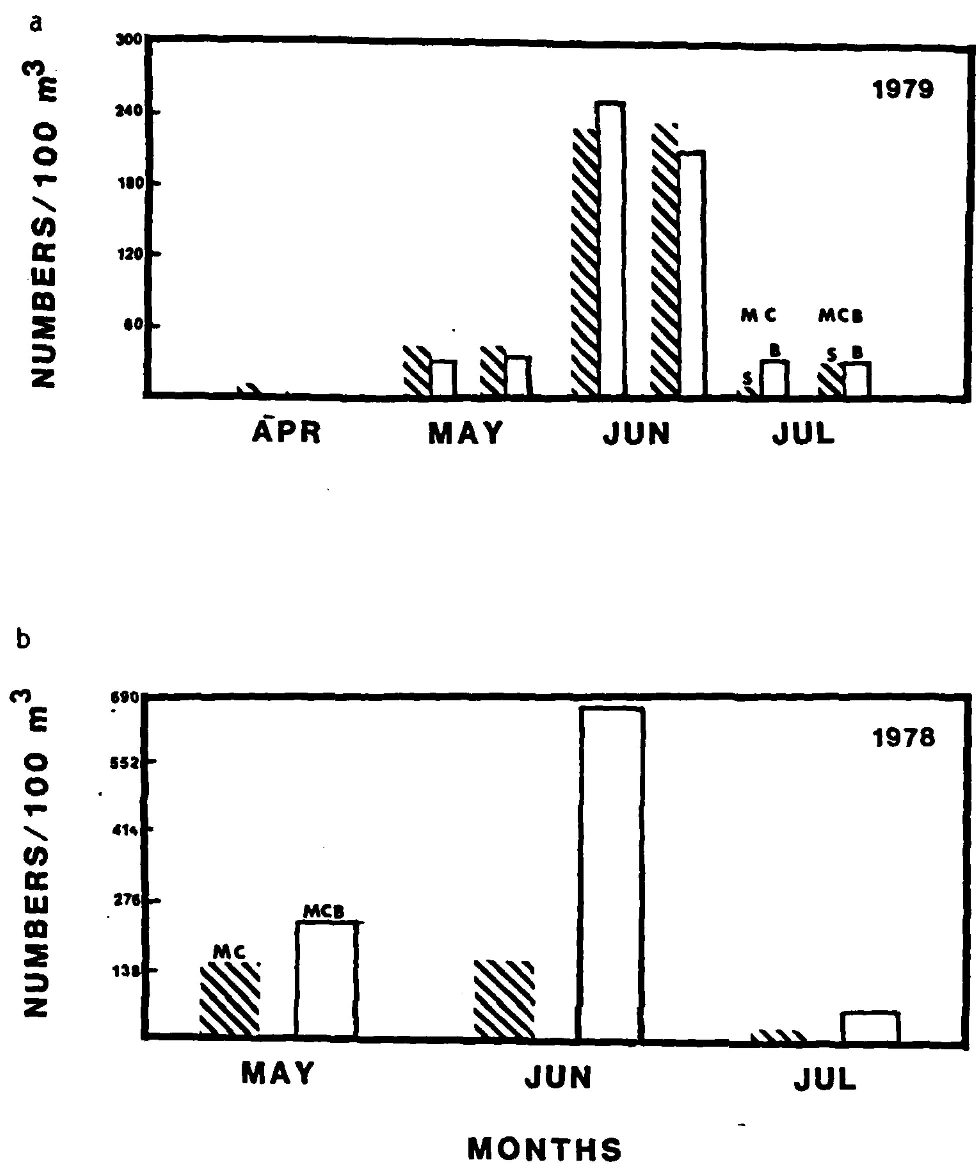

Fig. 14. Ichthyoplankton drift by month and habitat in Pool 14 (a) 1979 and (b) 1978. MC = main channel; MCB = main channel border; S = surface; B = bottom.

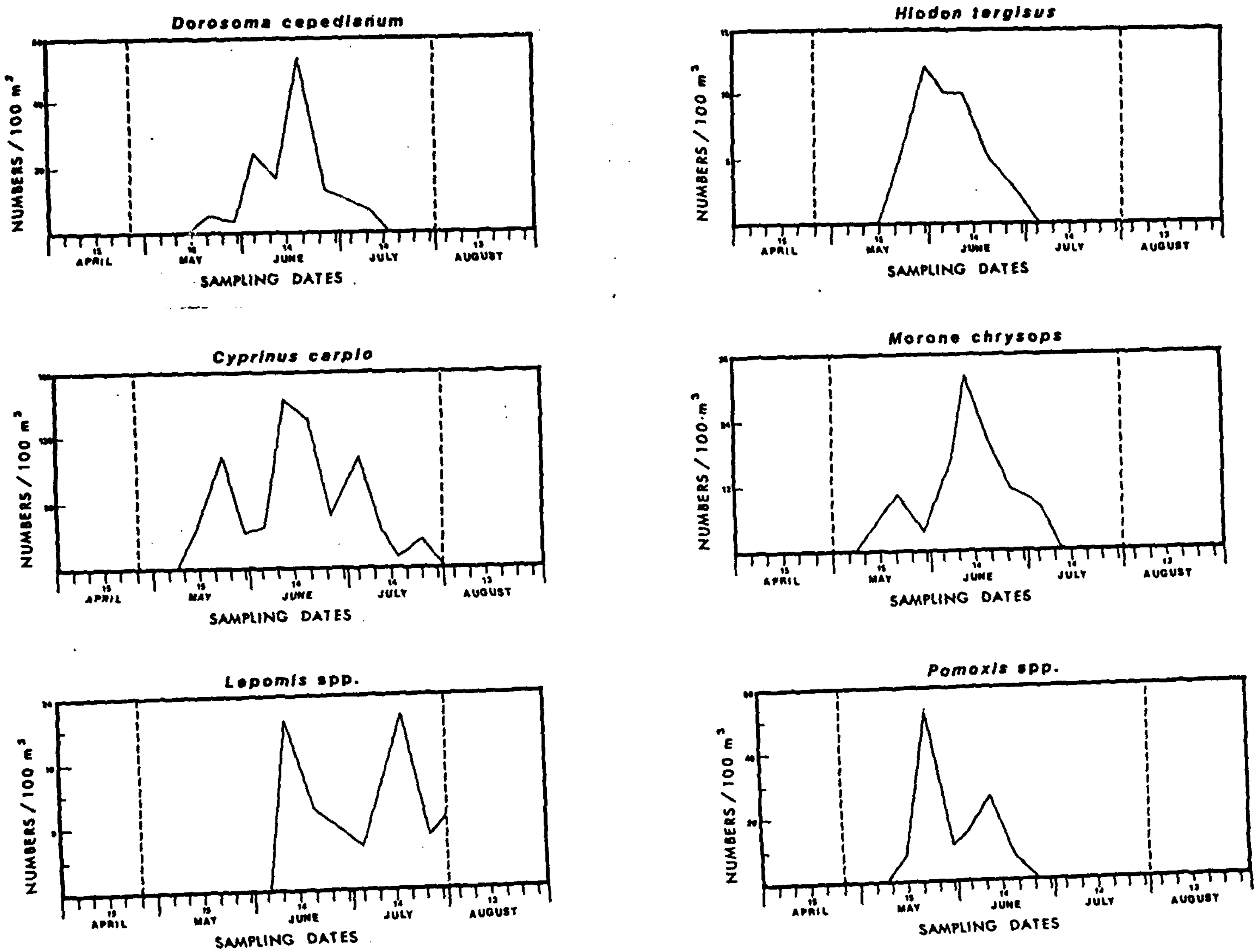

Fig. 15. Seasonal distribution of larval drift of selected species at main channel, main channel border and backwater sites in Pool 14, 1979.

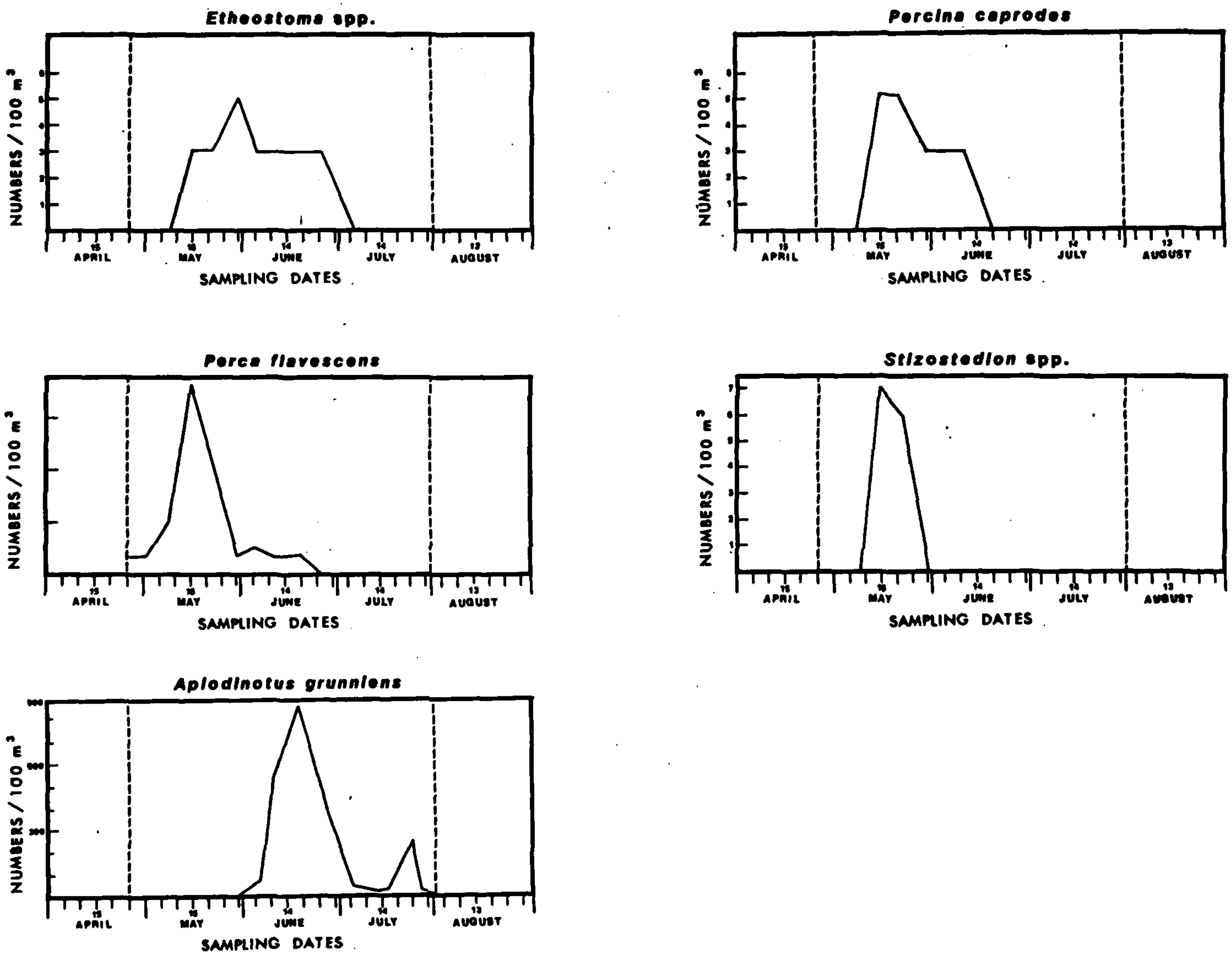

Fig. 15. Continued.

Table 26. Densities of fish larvae/100 m^3 for duplicate samples collected at main channel and main channel border sites in Pool 14 of the upper Mississippi River, near the Quad Cities, 1978. Numbers in parentheses are water temperature (°C).

Species	May			June			July			
	17 (13)	24 (17)	31 (23)	7 (23)	15 (22)	27 (25)	5 (26)	13 (24)	20 (26)	26 (25)
Lepisosteidae	0	0.1	0	0	0	0	0	0	0	0
Clupeidae										
Dorosoma cepedianum	0	0.1	1.6	10.4	10.2	1.6	2.1	0.0	0.0	0
Hiodontidae										
Hiodon tergisus	5.1	8.2	7.2	0.6	0.8	0.1	0.0	0	0	0
Cyprinidae										
Cyprinus carpio	3.8	2.2	142.5	47.2	78.7	109.8	16.2	9.1	0.3	0.4
Unidentified cyprinids	3.0	2.2	18.6	375.1	156.9	12.8	53.2	3.2	5.3	0.6
Catostomidae	340.8	7.6	19.1	10.0	18.4	6.7	5.8	1.4	16.0	1.2
Ictaluridae										
Ictalurus punctatus	0	0	0	0	0	0.2	1.5	1.8	0.2	1.6
Unidentified ictalurids	0	0	0	0	0.1	0	0	0	0	0.2
Percichthyidae										
Morone chrysops	0	0.7	1.0	2.2	0	0.3	0.1	0	0	0
Centrarchidae										
Lepomis spp.	0	0	0	5.3	1.6	1.1	1.4	0.6	0.4	0.4
Pomoxis spp.	0	0.2	0.8	1.2	1.3	0.0	0	0	0	0
Unidentified centrarchids	0	0	0.3	1.2	1.8	0.0	0	0	0	0
Percidae										
Perca flavescens	0.6	0	0	0.2	0	0	0	0	0	0
Percina caprodes	0	0	0.8	0.6	0	0	0	0	0	0
Stizostedion spp.	1.3	0.2	0.1	0	0	0	0	0	0	0
Unidentified percids	10.8	2.2	0.2	0	0.2	0	0	0	0	0
Sciaenidae										
Aplodinotus grunniens	0.3	0.1	15.8	109.5	69.4	35.3	12.2	2.9	0.7	5.3
Unidentified	3.8	1.4	1.6	2.4	5.4	0.4	0.3	0.2	0.4	1.1

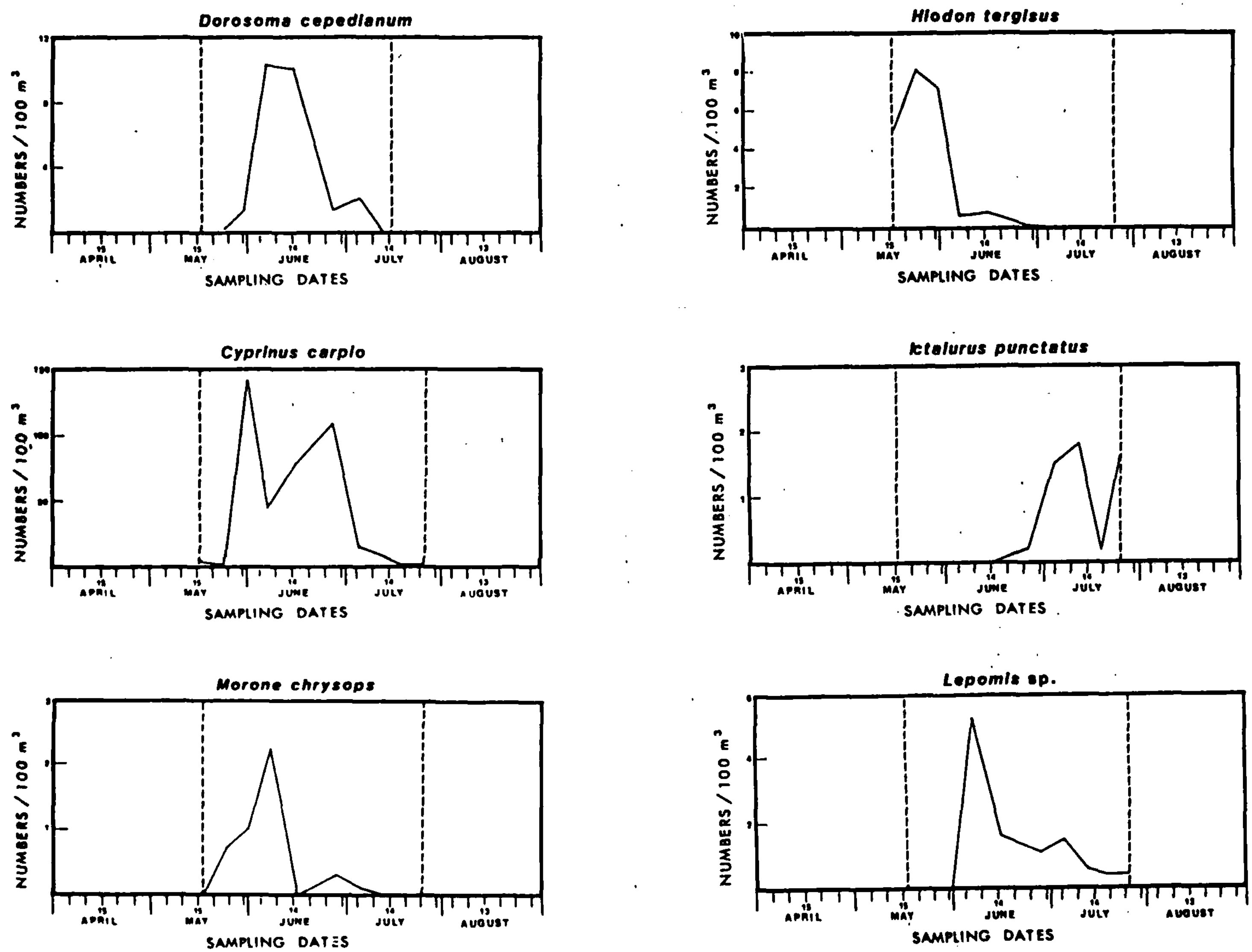

Fig. 16. Seasonal distribution of larval drift of selected species at main channel and main channel border sites in Pool 14, 1978.

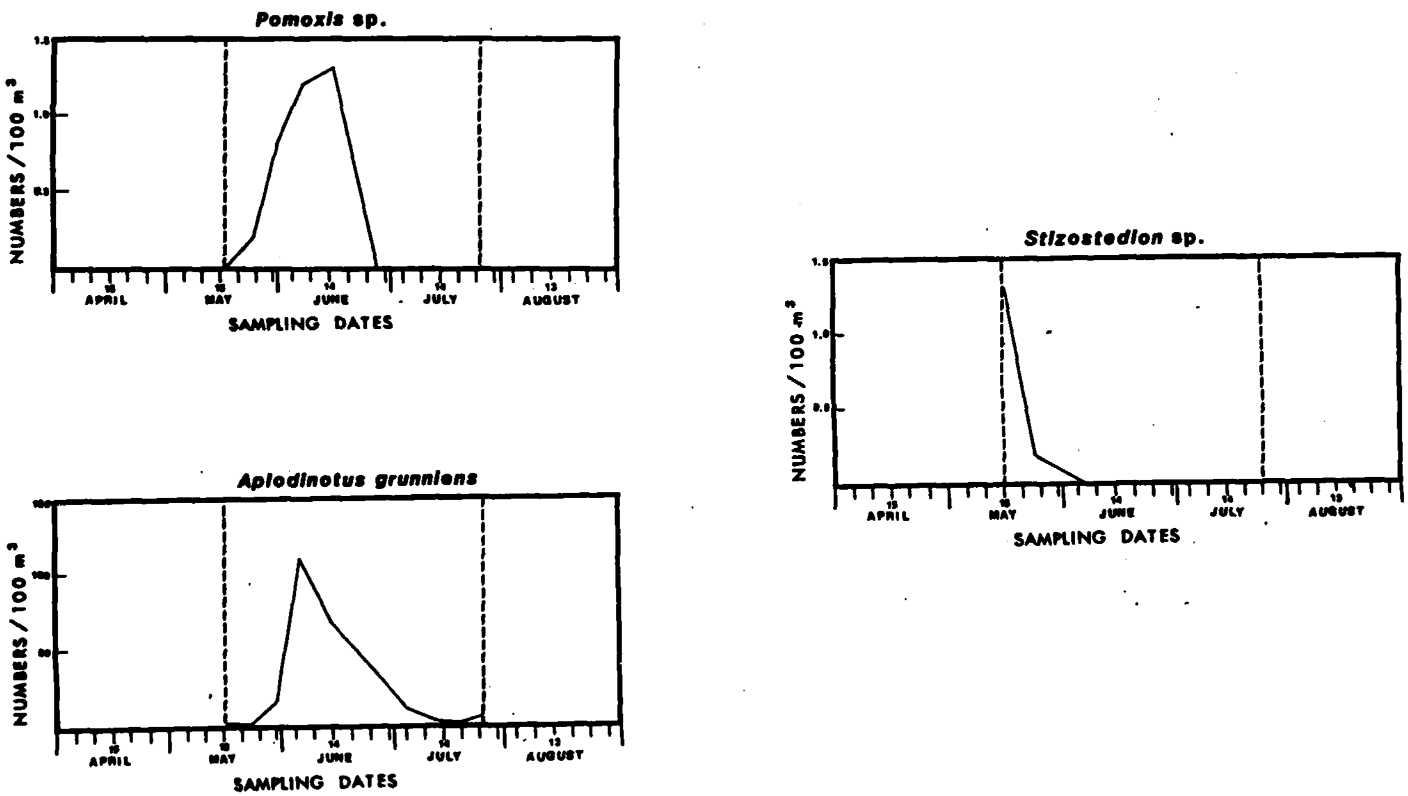

Fig. 16. Continued.

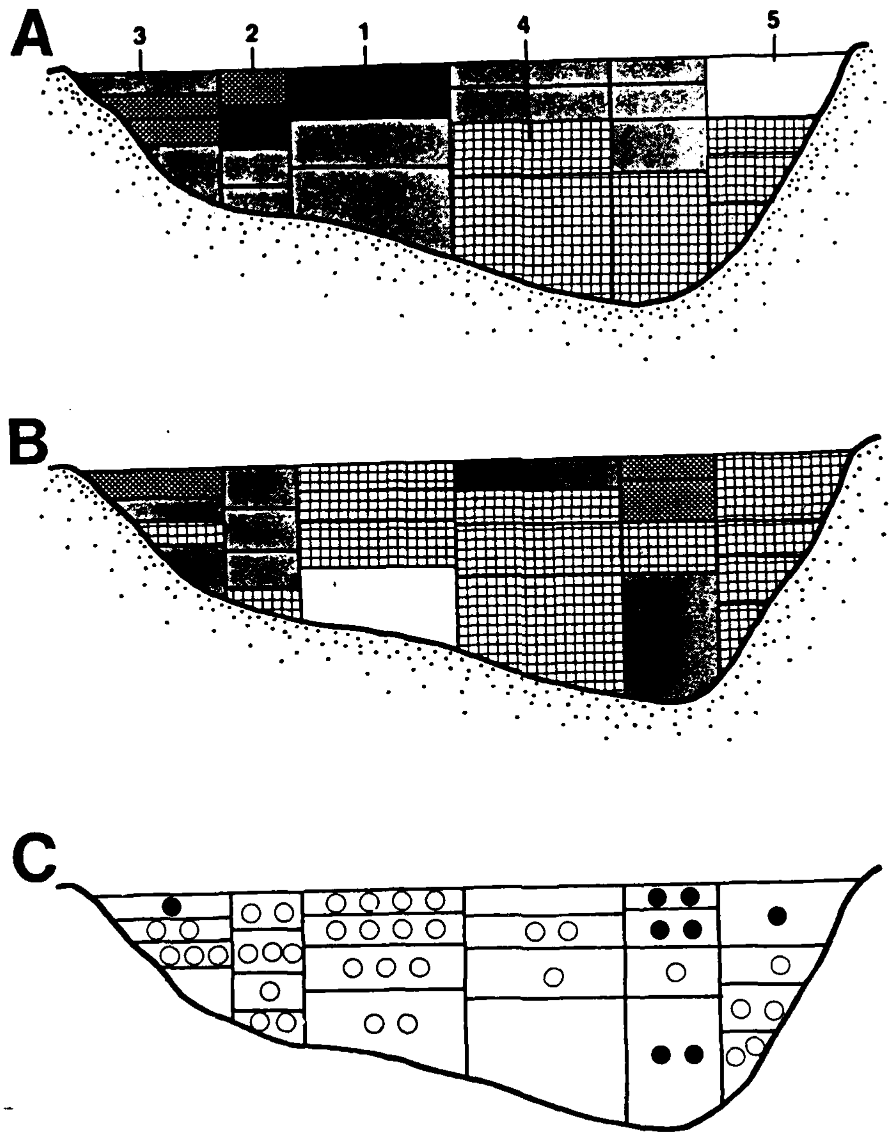

Fig. 17. Relative density of ichthyoplankton drift near the Quad-Cities Generating Plant, Pool 14, 1978 during the day (A) and night (B) and change in relative density from day to night (C). Relative magnitude of increases (day to night) shown by closed circle (●). Relative magnitude of decreases (day to night) shown by open circle (o).

* Areas of darkest shading (1) indicate sites of greatest ichthyoplankton densities. Sites of lowest ichthyoplankton densities indicated by white (5).

Table 27. Densities of fish larvae/100 m^3 collected at main channel and main channel border sites (subsurface and bottom combined) in Pool 14 of the upper Mississippi River near Quad-Cities Station, 1977. Numbers in parentheses are water temperature (°C).

Species	April		May				June					July				August					Sept.
	19 (19)	26 (16)	5 (20)	10 (19)	18 (24)	26 (26)	1 (24)	7 (23)	14 (22)	22 (24)	29 (24)	7 (26)	12 (27)	20 (28)	28 (25)	4 (24)	9 (24)	15 (23)	25 (21)	31 (23)	8 (24)
Clupeidae																					
Dorosoma cepedianum	0.0	0.1	1.4	2.8	0.1	2.3	1.3	3.3	1.8	4.6	6.0	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Hiodontidae																					
Hiodon tergisus	0.0	0.4	1.1	1.0	0.4	0.3	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cyprinidae																					
Cyprinus carpio	0.2	8.2	0.7	0.1	3.3	2.5	4.4	89.4	0.6	16.2	24.3	6.6	21.2	0.7	0.0	0.1	0.3	0.1	0.0	0.0	0.0
Notropis atherinoides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0
Unidentfied cyprinids	0.0	14.3	0.3	0.4	0.0	1.1	0.6	0.4	0.3	0.3	1.3	6.9	160.9	160.2	147.5	6.1	15.2	3.3	0.5	0.3	0.0
Catostomidae																					
Catostoma commersoni	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified catostomids	0.0	69.8	2.2	1.4	0.1	0.4	0.1	0.1	0.0	0.4	0.3	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ictaluridae																					
Ictalurus punctatus	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.1	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percichthyidae																					
Morone chrysops	0.0	0.0	0.7	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Centrarchidae																					
Lepomis spp.	0.0	0.0	0.0	0.0	0.0	0.3	0.9	2.4	1.4	1.5	13.2	3.4	9.6	2.0	2.6	0.7	1.1	0.3	0.0	0.0	0.1
Pomoxis spp.	0.0	11.6	2.7	2.0	1.0	1.1	0.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percidae																					
Etheostoma spp.	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Perca flavescens	0.0	6.5	2.8	1.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Percina caprodes	0.2	14.3	6.1	12.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stizostedion spp.	0.2	21.1	1.4	0.8	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified percids	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sciaenidae																					
Aplodinotus grunniens - larvae	0.0	0.0	0.0	1.5	0.8	0.3	1.7	15.6	3.0	7.7	19.9	12.4	42.0	27.6	35.1	10.4	8.1	2.1	0.3	0.1	0.0
- eggs	0.0	0.0	0.0	1.5	6.4	20.9	2.2	1.3	0.0	1.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unidentified - larvae	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.3	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
- eggs	0.0	0.2	0.0	0.2	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 28. Densities of fish eggs/100 m^3 collected in drift nets at main channel border (MCB) sites in Pool 14 of the upper Mississippi River near the Quad-Cities Station, 1977.

Species	April	May			June				July	
	26	10	18	26	1	7	14	22	7	12
Location 1 (MCB - Illinois side)										
Day										
Surface										
Aplodinotus grunniens	0	0	2.9	38.9	2.7	0	0	7.0	0	0
Bottom										
Aplodinotus grunniens	0	5.1	2.0	16.8	3.6	1.1	0	3.5	0	0
Night										
Surface										
Aplodinotus grunniens	0	3.5	0	0	1.2	4.6	0	0	0	0
Unidentified	1.2	0	0	0	0	0	0	0	0	0
Bottom										
Aplodinotus grunniens	0	0	0	1.0	7.1	2.2	0	0	0	0
Location 4 (MCB - Iowa side)										
Day										
Surface										
Aplodinotus grunniens	0	1.3	28.2	20.5	0	0	0	0	0	0
Unidentified	0	0	8.2	0	0	0	0	0	0	0
Bottom										
Aplodinotus grunniens	0	1.2	18.2	47.4	0	0	0	0	0	0
Unidentified	0	0	4.1	0	0	0	0	0	0	0
Night										
Surface										
Aplodinotus grunniens	0	0	0	0	0	1.3	0	0	0	0
Unidentified	0	1.2	0	0	0	0	0	0	0	0
Bottom										
Aplodinotus grunniens	0	1.2	0	2.6	3.1	1.1	0	0	0	0

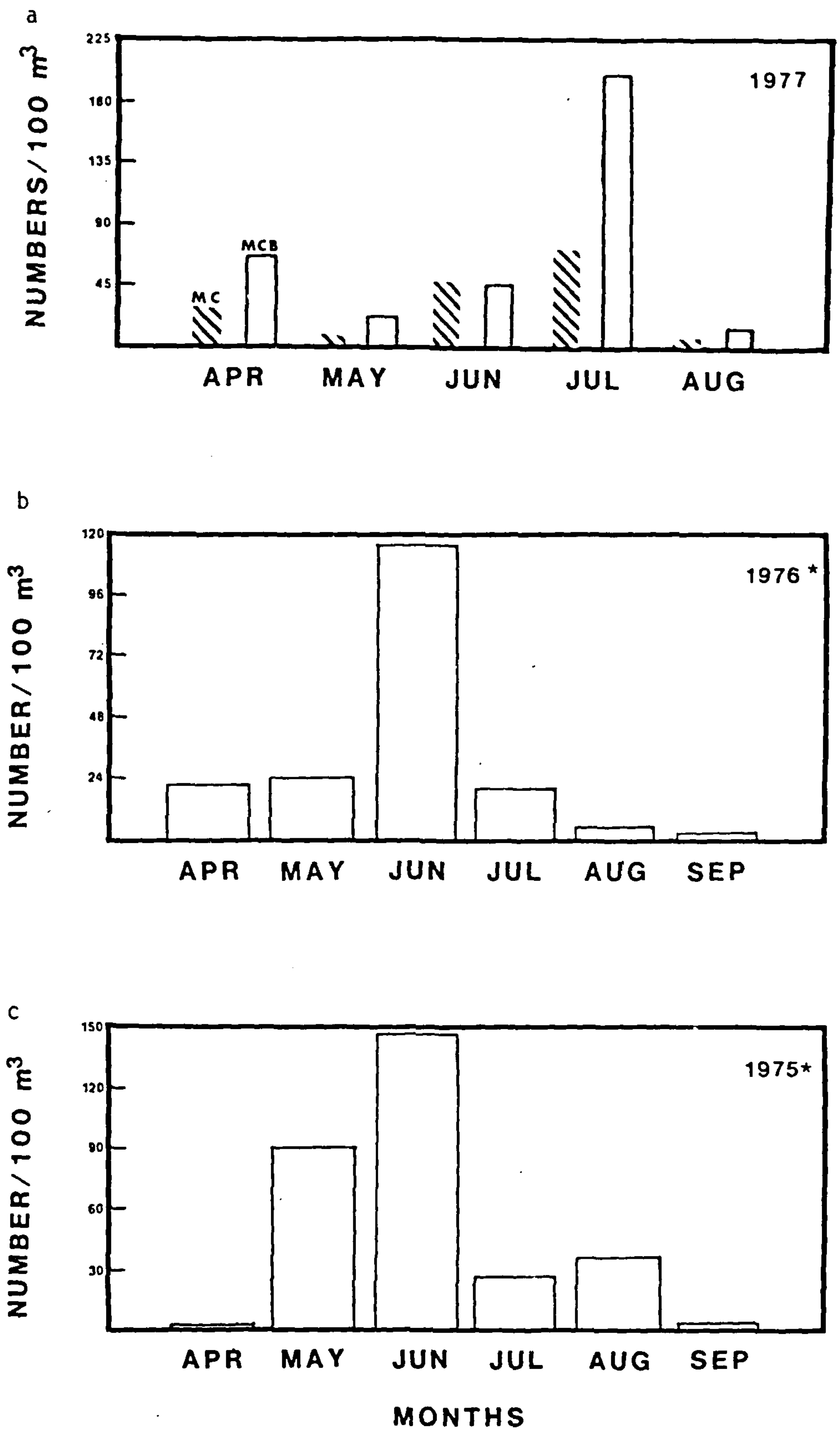

Fig. 18. Ichthyoplankton drift by month and habitat in Pool 14 for (a) 1977, (b) 1976, and (c) 1975. MC = main channel; MCB = main channel border. * Data for MC and MCB combined in original report.

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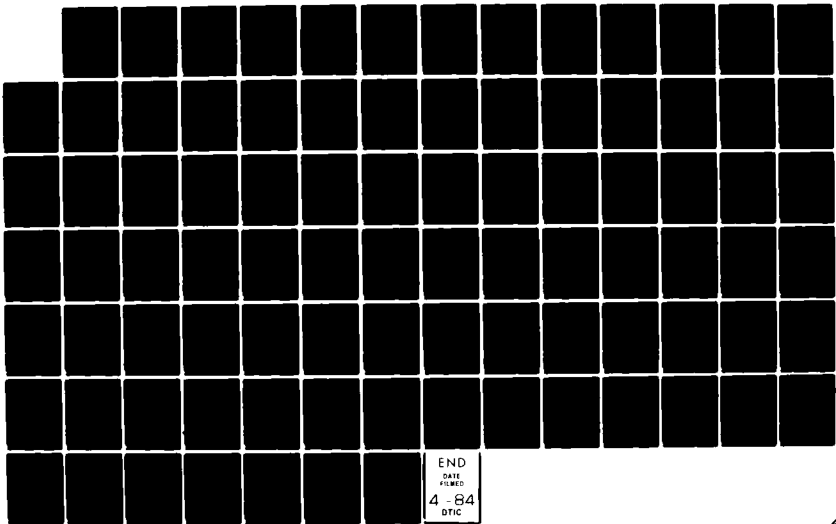

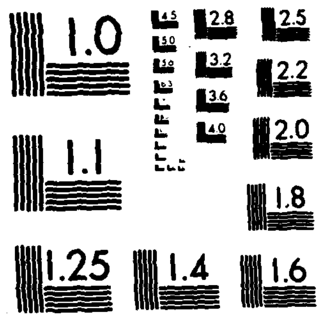

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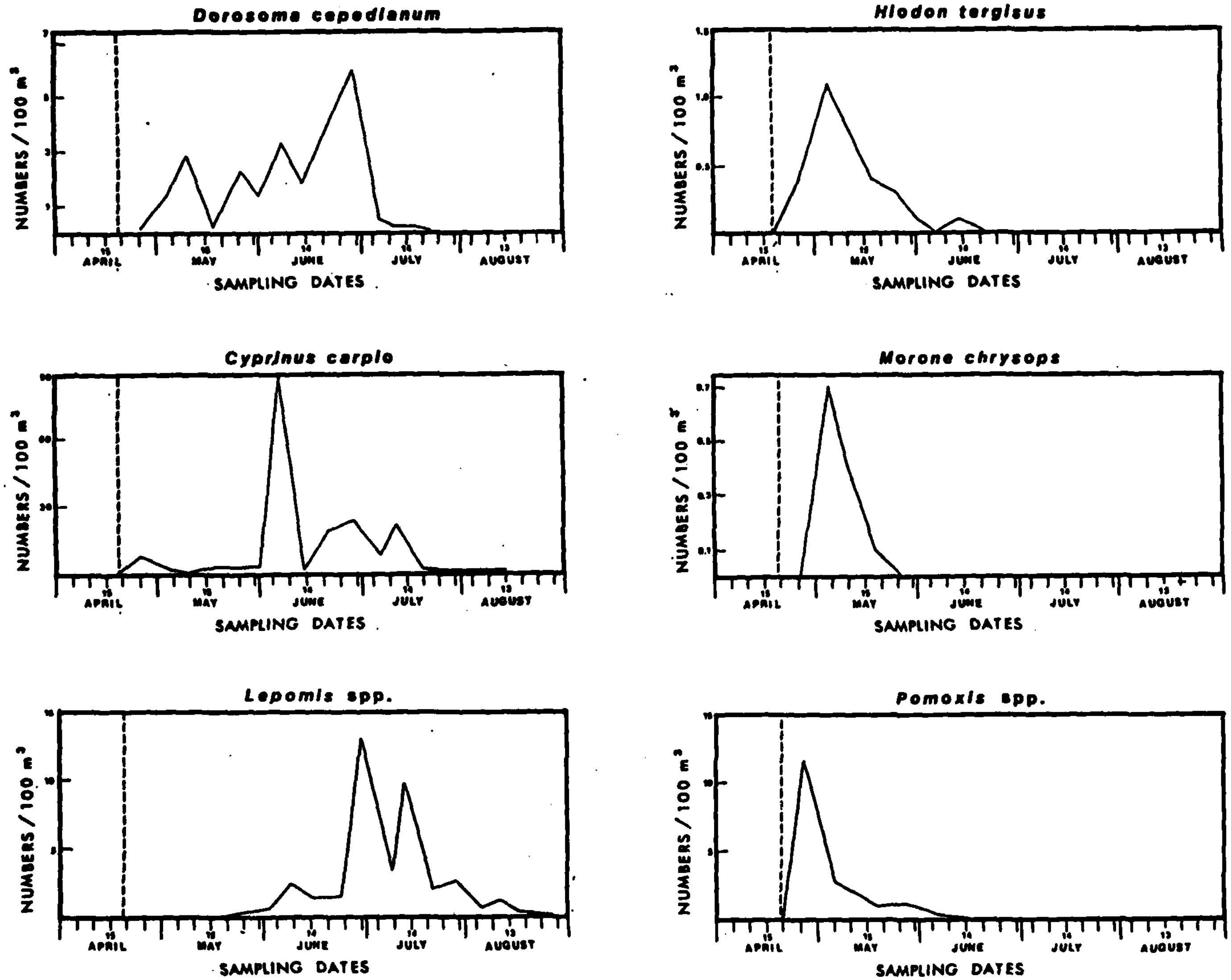


Fig. 19. Seasonal distribution of larval drift of selected species at main channel and main channel border sites (subsurface and bottom combined) in Pool 14, 1977.

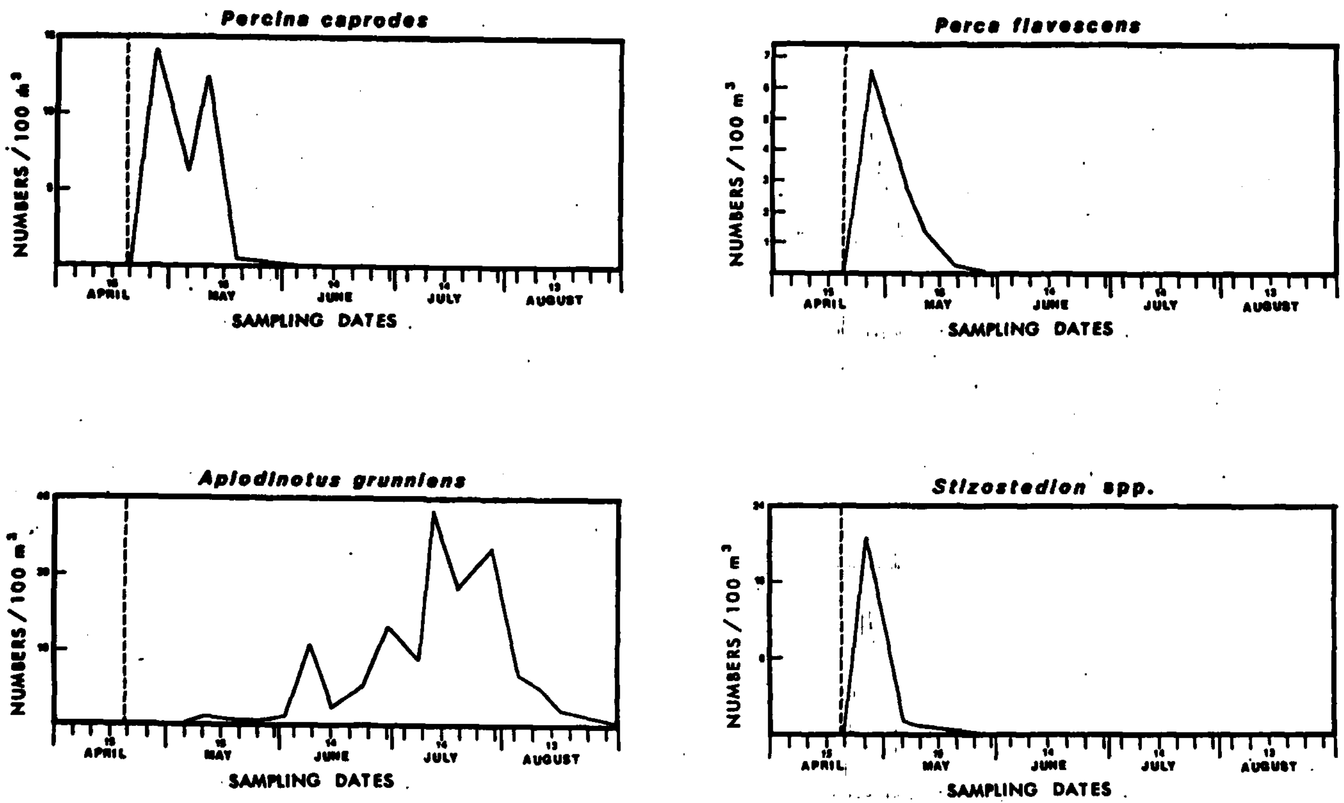


Fig. 19. Continued.

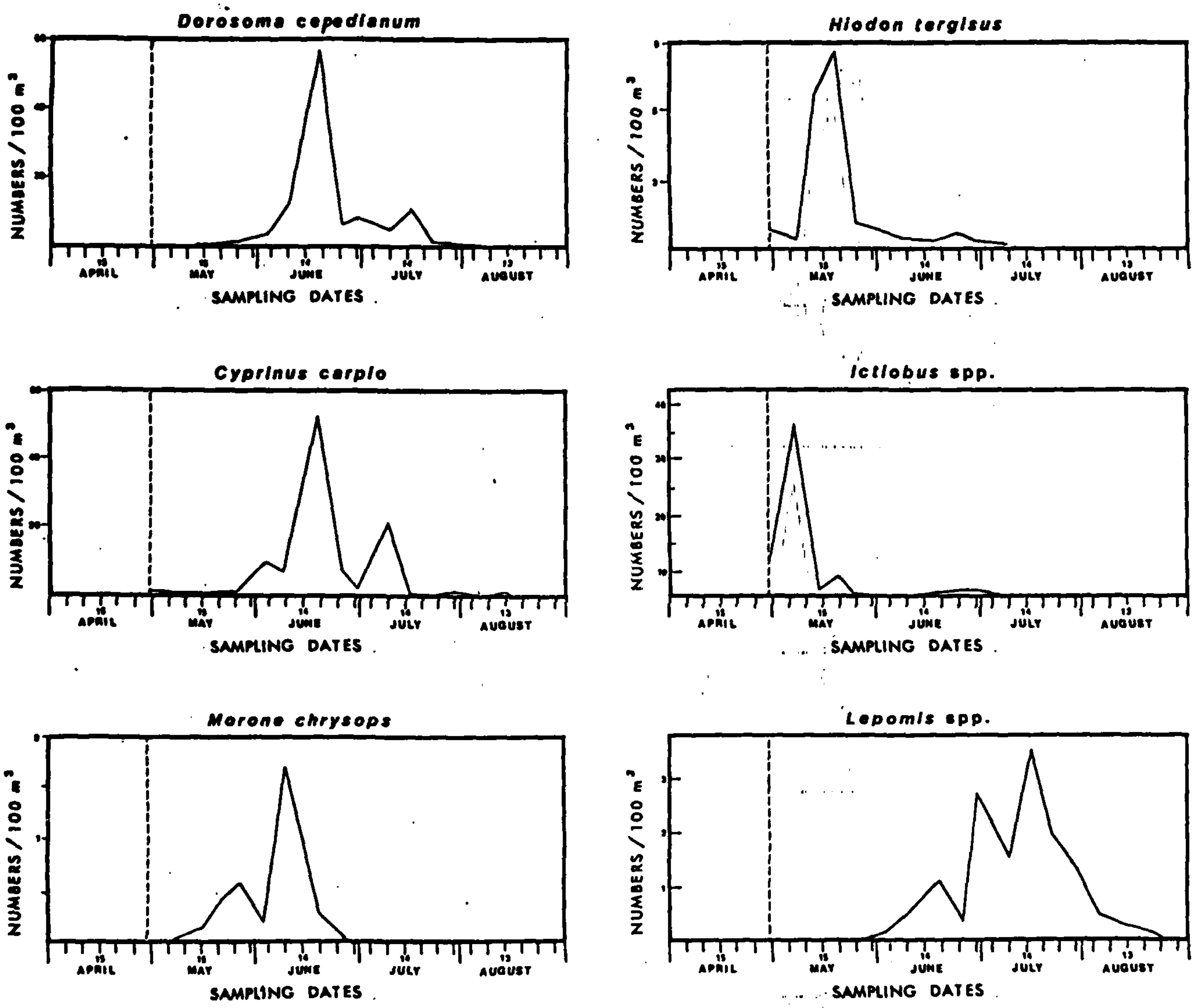


Fig. 20. Seasonal distribution of larval drift of selected species at main channel and main channel border sites in Pool 14, 1976.

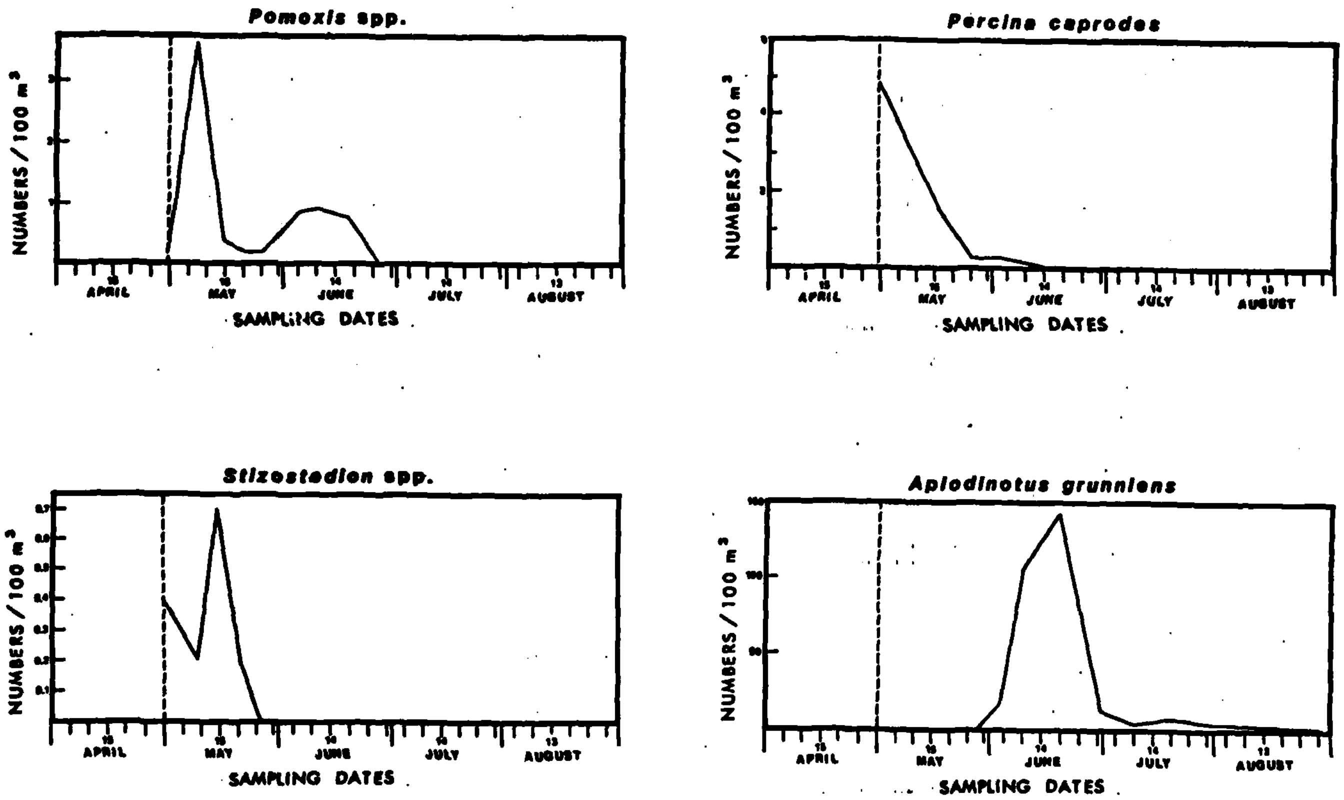


Fig. 20. Continued.

Table 29. Densities of fish larvae/100 m^3 collected at river transect locations (main channel and main channel border sites combined) in Pool 14 of the upper Mississippi River near Quad-Cities Station, 1976. Numbers in parentheses are water temperature (°C).

Species	April	May				June					July				August				September	
	29-30 (1)	6-7 (13)	13-14 (17)	20 (20)	25-26 (20)	3 (21)	8-9 (25)	17-18 (24)	25-26 (23)	29-30 (24)	8-9 (27)	15-16 (28)	22-23 (25)	29-30 (25)	5-6 (29)	12-13 (25)	19-20 (25)	26-27 (25)	2-3	10
Clupeidae																				
Dorosoma cepedianum	0	0	0	0.3	1.0	3.1	13.1	57.0	5.4	8.7	4.4	10.8	0.3	0.1	0	0	0	0	0	0
Hiodontidae																				
Hiodon tergisus	0.9	0.6	6.8	8.7	1.2	2.0	0.5	0.3	0.6	0.3	0	0	0	0	0	0	0	0	0	0
Esocidae																				
Esox lucius	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyprinidae																				
Cyprinus carpio	1.4	0.3	0	0.2	0.1	9.7	6.6	50.4	7.5	2.6	21.9	1.7	0.8	0.5	0.1	0	0	0	0	0
Unidentified cyprinids	0	0.2	0.1	0.1	0.6	2.2	23.6	1.2	0.5	0.3	0.1	0.2	0	1.1	1.7	0.7	0.3	0.3	1.1	0
Catostomidae																				
Ictiobus spp.	11.9	36.0	2.7	7.4	1.0	0	0	0	0.1	0.1	0	0	0	0	0	0	0	0	0	0
Unidentified catostomids	0	0.5	0.2	0	0.1	0.1	1.8	0.9	0.4	0	0	0	0	0	0	0	0	0	0	0
Ictaluridae																				
Ictalurus punctatus	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0	0	0	0
Percichthyidae																				
Morone chrysops	0	0	0.1	0.4	0.8	0.2	1.7	0.3	0	0	0	0	0	0	0	0	0	0	0	0
Centrarchidae																				
Lepomis spp.	0	0	0	0	0	0.2	0.5	1.1	0.4	2.7	1.5	3.5	1.9	1.3	0.5	0.3	0.2	0	0	0
Pomoxis spp.	0.1	3.7	0.4	0.2	0.2	0.8	0.9	0.7	0	0	0	0	0	0	0	0	0	0	0	0
Percidae																				
Percina caprodes	4.8	3.2	1.8	0.3	0.3	0.1	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
Stizostedion spp.	0.4	0.2	0.7	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified percids	0	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sciaenidae																				
Aplodinotus grunniens - larvae	0	0	0	0	7.8	15.0	104.3	143.5	75.6	12.2	3.4	7.0	6.9	3.0	4.6	1.0	1.0	0.7	0.7	0
- eggs	0	0	0	0	0.9	18.9	73.9	0.5	0.8	0.6	0	0	0	0	0	0	0	0	0	0
Unidentified - larvae	0.2	0.2	0.5	0.1	0.2	0.2	0.3	0	0.1	0	0.3	0.1	0	0	0	0	0	1.0	0	0
- eggs	0.8	1.0	0.6	1.2	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 30. Densities of fish eggs/100 m^3 collected at main channel border (MCB) sites in drift nets in Pool 14 of the upper Mississippi River near the Quad-Cities Station, 1976.

Species	April	May				June					July		
	29	7	13	20	25	3	8	17	24	29	8	15	22
Location 1 (MCB - Illinois side)													
Day													
Surface													
Aplodinotus grunniens	0	0	0	0	0	22.6	133.4	1.5	1.7	2.6	0	0	0
Unidentified	0	2.6	0	1.4	0	0	0	0	0	0	0	0	0
Bottom													
Dorosoma cepedianum	0	0	0	0	0	0	25.5	0	0	0	0	0	0
Aplodinotus grunniens	0	0	0	0	0	26.3	81.2	0	1.5	0	0	0	0
Unidentified	0	3.6	1.3	1.2	0	0	0	0	0	0	0	0	0
Night													
Surface													
Aplodinotus grunniens	0	0	0	0	1.4	30.8	3.9	0	0	0	0	0	0
Unidentified	3.3	0	0	1.4	1.2	0	0	0	0	1.4	0	0	0
Bottom													
Dorosoma cepedianum	0	0	0	0	0	0	1.7	0	0	0	0	0	0
Aplodinotus grunniens	0	0	0	0	2.5	28.1	73.9	1.2	0	0	0	0	0
Unidentified	2.7	0	3.7	0	0	0	0	0	0	0	0	0	0
Location 4 (MCB - Iowa side)													
Day													
Surface													
Dorosoma cepedianum	0	0	0	0	0	0	4.9	0	0	0	0	0	0
Aplodinotus grunniens	r	0	0	0	1.6	26.0	170.2	0	3.1	2.3	0	0	0
Unidentified		0	0	2.0	0	0	0	0	0	0	0	0	0
Bottom													
Dorosoma cepedianum	0	0	0	0	0	0	1.5	0	1.8	0	0	0	0
Aplodinotus grunniens	0	0	0	0	1.4	6.4	80.1	0	0	0	0	0	0
Unidentified	0	1.6	0	0.9	0	0	0	0	0	0	0	0	0
Night													
Surface													
Aplodinotus grunniens	0	0	0	0	0	1.8	8.5	1.2	0	0	0	0	0
Unidentified	0	0	0	3.0	0	0	0	0	0	0	0	0	0
Bottom													
Hiodon tergisus	0	0	0	1.5	0	0	0	0	0	0	0	0	0
Aplodinotus grunniens	0	0	0	0	0	9.3	40.0	0	0	0	0	0	0
Unidentified	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 31. Densities of fish larvae/100 m^3 collected at the river transect locations (main channel and main channel border sites combined) in Pool 14 of the upper Mississippi River near Quad-Cities Station, 1975. Numbers in parentheses are water temperature (°C).

Species	April	May				June					July				August				Sept.
	28-29 (10)	6-7 (13)	15-16 (16)	20-21 (17)	28-29 (20)	2-3 (23)	10-11 (21)	15-16 (22)	25-26 (21)	29-30 (26)	7-8 (28)	16-17 (25)	23-24 (25)	30-31 (27)	6-7 (29)	10-11 (25)	20-21 (24)	24-25 (26)	4-5 (23)
Clupeidae																			
Dorosoma cepedianum	0	0	0	0.3	0.3	3.5	2.9	7.6	2.2	0.5	0.2	0	0	0	20.1	0	0	0	0
Hiodontidae																			
Hiodon tergisus	0	0	0.3	2.7	3.1	1.4	0.6	0.3	0.1	0.1	0	0	0	0	0	0	0	0	0.1
Esocidae																			
Esox lucius	0	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyprinidae																			
Cyprinus carpio	0	0	108.0	47.4	20.1	3.8	10.4	4.3	2.1	4.4	25.1	0.2	2.2	15.1	3.6	1.2	0.8	0.2	0.1
Unidentified cyprinids	0	0	0	0.1	1.7	3.9	4.6	1.0	29.6	6.9	2.7	0	4.5	1.7	0	0	0	0	0
Catostomidae																			
Catostomus commersoni	0	0	0.1	0.3	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ictiobus spp.	0	0	14.0	17.6	2.1	0.4	0	0	0	0	0	0	0	0	0	0	0	0	0
Unitdentified catostomids	0	0	0	0.1	3.8	7.0	6.6	0.8	2.7	2.8	0.7	0.1	0.2	0	0	0	0	0	0
Ictaluridae																			
Ictalurus punctatus	0	0	0	0	0	0	0	0	0	0.2	0.7	0	0.2	0	0	0	0	0	0
Percichthyidae																			
Morone chrysops	0	0	0	0.7	15.4	24.6	40.1	12.6	1.8	0.1	0.5	0	0	0	0	0	0	0	0
Centrarchidae																			
Lepomis spp.	0	0	0	0	0	0.6	0.1	0.8	2.1	1.0	1.4	0	0.2	0	0	0	0	0	0
Pomoxis spp.	0	0	0.2	3.6	6.0	6.9	0.6	0.4	0	0.2	0	0	0	0	0	0	0	0	0
Percidae																			
Stizostedion spp.	0	0.1	0.3	0.6	0.7	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0
S. canadense	0	0.1	0.2	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S. vitreum	0	0	0.2	0.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unidentified percids	0	0	3.4	4.6	0.3	0.1	0.2	0	0	0	0	0	0	0	0	0	0	0	0
Sciaenidae																			
Aplodinotus grunniens	0	0	0	0	79.7	158.0	148.1	57.7	113.3	27.8	6.4	0	5.2	21.4	0	0	0	0	0

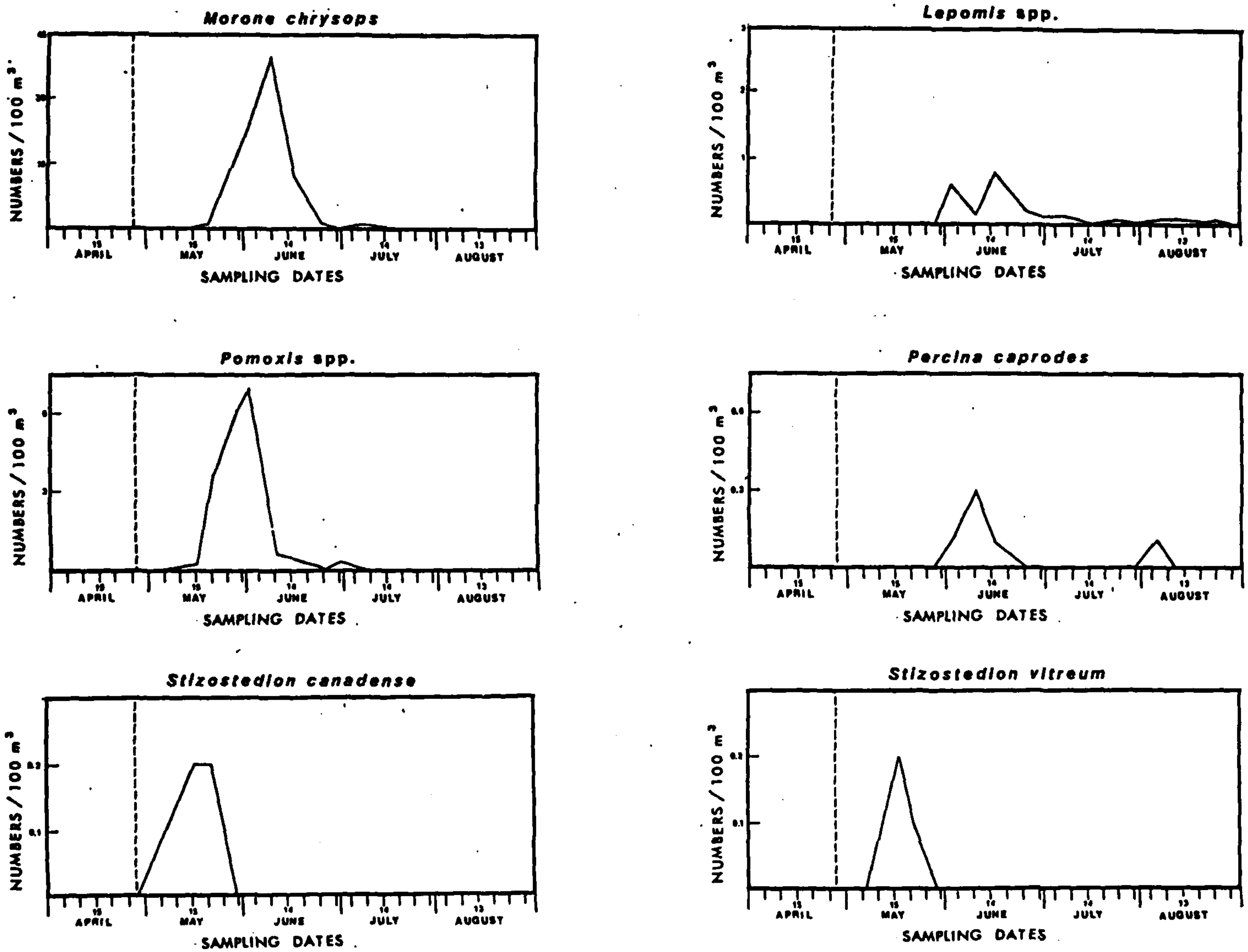
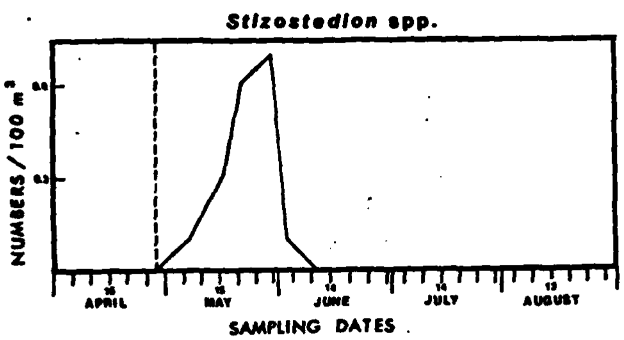


Fig. 21. Seasonal distribution of larval drift of selected species at main channel and main channel border sites in Pool 14, 1975.



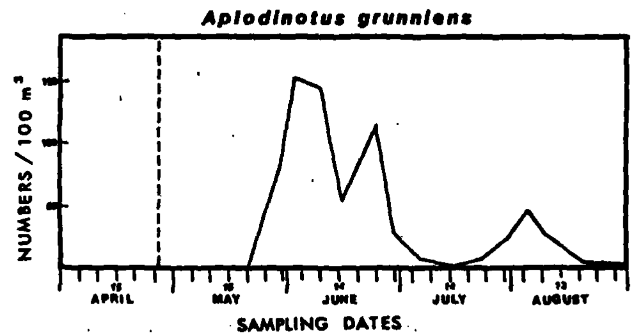


Fig. 21. Continued.

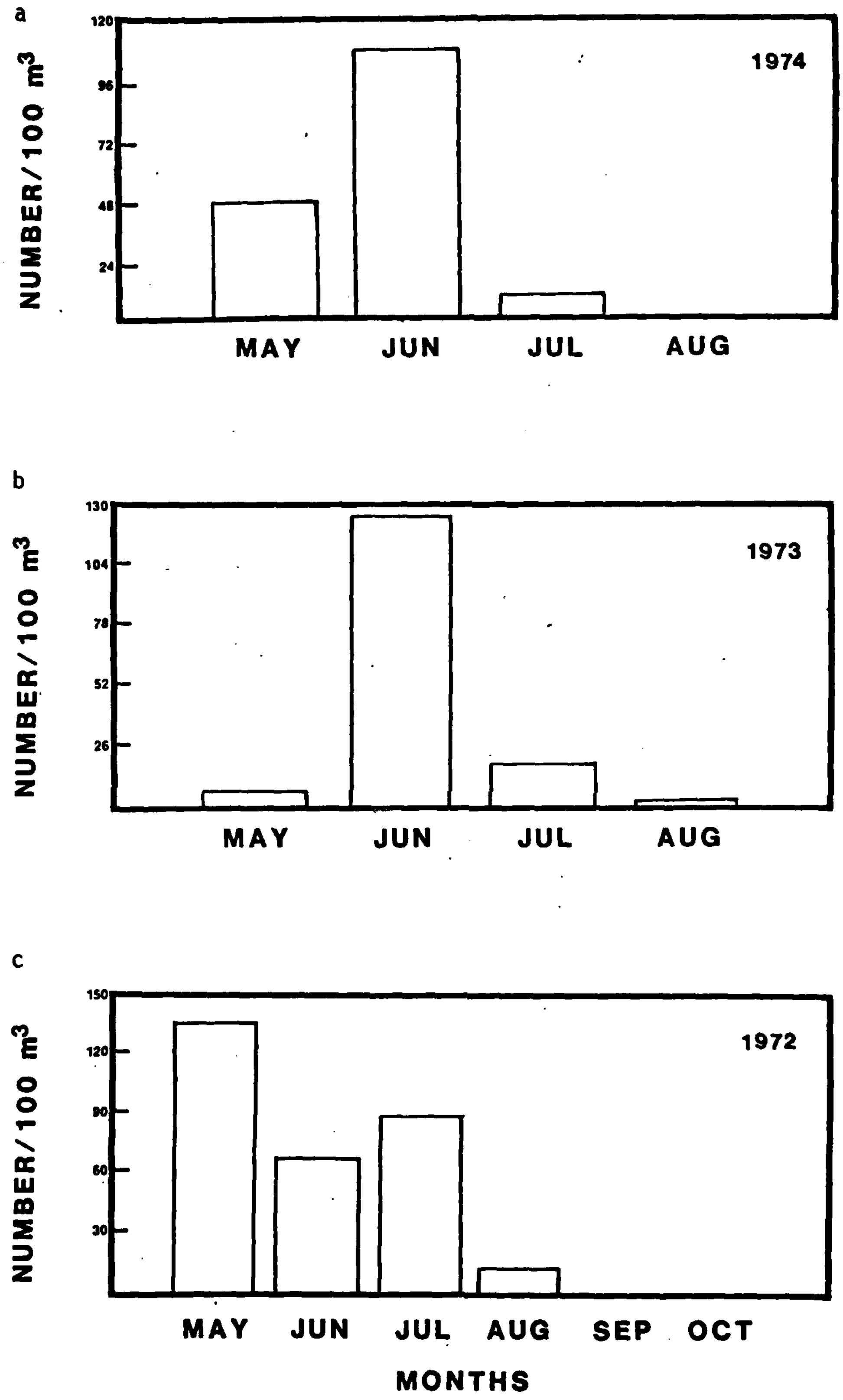


Fig. 22. Ichthyoplankton drift by month in Pool 14 in the main channel for (a) 1974, and at main channel and main channel border sites for (b) 1973, and (c) 1972.

Table 32. Total number of each species of fish larvae collected in drift nets set in the main channel in Pool 14 of the upper Mississippi River near the Quad-Cities Station, 1974.

Species	May				June				July				August			
	8	15	23	29	4	11	19	26	3	10	17-19	25-26	1	7	14	22
Clupeidae																
Dorosoma cepedianum	1	0	1	3	0	18	44	0	0	0	0	0	0	0	0	0
Hiodontidae																
Hiodon tergisus	0	1	0	0	4	0	0	0	0	0	0	0	0	0	0	0
Cyprinidae																
Cyprinus carpio	9	0	2	17	1	17	21	230	14	1	4	1	0	0	0	0
Notropis spp.	1	0	0	0	0	3	1	0	0	0	0	0	0	1	4	0
Catostomidae																
Catostomus commersoni	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0
Ictiobus spp.	66	36	0	9	0	0	0	0	0	0	0	0	0	0	0	0
Moxostoma spp.	0	0	0	0	0	0	1	0	4	0	0	0	0	0	0	0
Percichthyidae																
Morone chrysops	0	0	0	1	0	4	0	0	1	0	0	0	0	0	0	0
Centrarchidae																
Lepomis spp.	5	0	0	0	1	1	1	14	0	2	0	0	0	0	2	0
Pomoxis spp.	0	0	3	0	0	7	12	8	0	0	0	0	0	0	0	0
Percidae																
Perca flavescens	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Sciaenidae																
Aplodinotus grunniens	1	0	0	0	1	5	32	26	35	24	1	0	2	5	4	3
Unidentified	2	0	0	1	101	4	11	17	0	1	0	0	0	0	0	1

Table 33. Total numbers of each species of fish larvae collected at main channel and main channel border sites in drift nets in Pool 14 of the upper Mississippi River near Quad-Cities Station, 1973.

Species	May	June	July	August
Clupeidae				
Dorosoma cepedianum	1	104	13	0
Hiodontidae				
Hiodon tergisus	16	42	0	0
Cyprinidae				
Cyprinus carpio	13	937	73	3
Hybopsis spp.	0	3	0	0
Notropis spp.	261	98	12	10
Percichthyidae				
Morone chrysops	0	5	0	0
Centrarchidae				
Lepomis spp.	13	2	16	4
Pomoxis spp.	0	7	0	0
Percidae				
Etheostoma spp.	2	0	0	0
Perca flavescens	2	0	0	0
Stizostedion spp.	2	0	0	0
Sciaenidae				
Aplodinotus grunniens	0	1,076	77	8
Unidentified	5	129	0	0

Table 34. Total numbers of each species of fish larvae collected at main channel and main channel border sites in drift nets in Pool 14 of the upper Mississippi River, 1972.

Species	May	June	July	August
Clupeidae				
Dorosoma cepedianum	18	36	82	7
Hiodontidae				
Hiodon tergisus	257	2	2	0
Esocidae				
Esox spp.	3	0	0	0
Esox lucius	1	0	0	0
Cyprinidae				
Campostoma anomalum	15	0	0	0
Cyprinus carpio	175	364	662	308
Notemigonus crysoleucas	0	0	1	0
Notropis spp.	3,523	424	1,204	154
N. atherinoides	0	1	0	1
Unidentified cyprinids	0	1	0	1
Catostomidae				
Carpiodes carpio	9	0	1	0
C. cyprinus	21	0	0	0
Catostomus commersoni	2	0	0	0
Moxostoma spp.	14	0	0	0
Ictaluridae				
Ictalurus punctatus	0	1	6	2
Unidentified ictalurids	0	0	1	0
Percichthyidae				
Morone chrysops	16	6	5	1
Centrarchidae				
Lepomis spp.	43	14	14	2
L. gibbosus	0	1	0	0
L. macrochirus	0	2	6	2
Micropterus spp.	1	0	0	0
M. salmoides	4	0	1	0
Pomoxis spp.	27	4	17	1
Percidae				
Perca flavescens	28	0	0	1
Percina caprodes	7	0	0	0
Stizostedion spp.	7	0	0	0
S. vitreum	16	0	0	0
Sciaenidae				
Aplodinotus grunniens	497	786	1,473	16
Unidentified	22	9	20	9

Table 35. Total numbers of fish larvae collected in drift nets (main channel, main channel border, and backwater areas combined) in Pool 14 of the upper Mississippi River, 1971.

	April	May				June				July				August				Sept.	
Species	29	12	25	26	28	9	12	22	30	1	15	28	30	11	25	26	29	8	22
Clupeidae																			
Dorosoma cepedianum	0	0	0	0	0	2	0	0	2	0	0	1	0	0	0	0	0	0	0
Hiodontidae																			
Hiodon tergisus	0	7	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyprinidae																			
Cyprinus carpio	0	0	0	0	0	91	486	0	0	1	0	0	0	0	0	1	0	0	0
Unidentified cyprinds*	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Catostomidae	0	14	0	23	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ictaluridae																			
Ictalurus punctatus	0	0	0	0	0	0	0	0	15	0	4	0	0	0	0	0	0	0	0
Percichthyidae																			
Morone chrysops	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Centrarchidae																			
Micropterus salmoides	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Unidentified centrarchids**	0	0	4	0	0	0	0	0	71	18	2	0	0	0	0	0	0	0	0
Percidae																			
Stizostedion spp.	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sciaenidae																			
Aplodinotus grunniens	0	0	0	0	0	9	143	0	3,140	89	125	0	11	3	3	15	1	1	3

* Some of these minnows are too large to be included as larval fish.

** Probably bluegills

3. SPECIES COMPOSITION OF UMR ICHTHYOPLANKTON DRIFT

Of the over 147 species of fishes that occur in the Upper Mississippi River (Van Vooren 1983), 27 species are known or suspected to occur regularly in the drifting ichthyoplankton of the main channel (Table 36). Five species were abundant in the drift, six were common, four were occasional, and three were uncommon. Several species are suspected to occur in the drift based on their reproductive stategies, but have not been identified in the drift in the main channel. In addition to having larval stages in the drift, eggs of *Hiodon alosoides*, *H. tergisus*, *Lota lota*, and *Aplodinotus grunniens* are also present.

REFERENCE

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Table 36. Identification of fish species known or suspected to occur regularly in the UMR main channel ichthyoplankton drift*.

Species	Life stage	(Relative abundance)**
Acipenseridae		
Scaphirhynchus platorynchus	larva	?
Polyodontidae		
Polyodon spathula	larva	?
Clupeidae		
Dorosoma cepedianum	larva	A
Hiodontidae		
Hiodon alosoides	egg, larva	?,?
Hiodon tergisus	egg, larva	U,C
Cyprinidae***		
Cyprinus carpio	larva	A
Hybopsis aestevalis	egg	O
Notropis atherinoides	larva	A
Catostomidae		
Carpiodes carpio	larva	C
Carpiodes cyprinus	larva	C
Carpiodes velifer	larva	?
Ictiobus bubalus	larva	C
Ictiobus cyprinellus	larva	C
Moxostoma macrolepidotum	larva	?
Ictaluridae		
Ictalurus punctatus	alevin	U
Pylodictis olivaris	alevin	?
Godidae		
Lota lota	egg, larva	?,?
Percichthyidae		
Morone chrysops	larva	A
Morone mississippiensis	larva	?
Centrarchidae		
Lepomis macrochirus	larva	O
Pomoxis annularus	larva	?
Pomoxis nigromaculatus	larva	C
Percidae		
Percina flavescens	larva	O
Percina caprodes	larva	U
Stizostedion canadense	egg, larva	?,U
Stizostedion vitreum	larva	O
Sciaenidae		
Aplodinotus grunniens	egg, larva	A,A

* Data compiled from references discussed throughout the text.

** Relative abundance: A - abundant, is predominant in samples; C - common, occurs regularly in samples; O - occasional, irregular occurrence in samples, but may be numerous at times; U - uncommon, represented by only a few caught individuals; and, ? - suspected to occur in drift based on reproductive strategy and the behavior of other closely related species.

*** Many more species of cyprinids may occur in the drift, but because of limitations in identification of larvae to species most studies have simply recorded individuals as unidentified cyprinids. Therefore, there is insufficient data to comment on the possibility of other species occurring in the drift.

4. GUILD ASSIGNMENTS

Feeding, reproductive, and economic guilds (Table 37) were assigned to fishes known or suspected to occur in the ichthyoplankton drift in the main channel of the UMR. This provided a framework for selection of representative important fish species for future study (Table 38).

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Table 37. Definitions of guilds applied to species known or suspected to occur in UMR main channel ichthyoplankton drift.

General guild	Specific guild
Reproductive Guild	*Non-guarder-open stratum*
Species of fish, which utilize similar reproductive strategies, based on the physical parameters of their spawning and nursery habitats and on early life history behavior patterns.	Pelagophils: Nonadhesive eggs are released and scattered in the open water column. Near neutral or positively buoyant eggs. Larvae swim constantly and are positively phototropic.
	Litho-pelagophils: Eggs are deposited on rocks or gravel, but larvae become buoyant and water currents carry them downstream.
	Lithophils. Eggs are deposited on rocks etc. Larvae are highly photophobic.
	Phyto-lithophils: Eggs are deposited on submerged vegetation or logs, gravel, rocks. Many of the species have larvae with cement glands. Larvae usually closely associated with vegetation.
	Phytophils: Eggs are adhesive and attach to vegetation, logs, etc. Larvae have cement glands and are not photophobic.
	Psammophils: Eggs are adhesive and scattered on sand or roots. Larvae are photophobic.
	Guarder-substrate chooser
	Phytophils: Adhesive eggs are scattered or attached to vegetation. Male guards the nest. No cement glands. Larvae swim instantly to avoid anoxic mud bottoms.
	Guarder-nest spawner
	Lithophils: Eggs are deposited in a single-layer or multi-layer on cleaned areas of rocks or in pits in gravel.
	Phytophils: Members are adapted to nesting above or on a mud bottom.
	Speleophil: Eggs are deposited and guarded in natural holes or cavities or in specially constructed burrows.
Feeding Guilds	Open-water
Species of fish whose adult stage incorporates the same general types of food and feeding position in the water column.	Omnivore: Adults feed up in the water column on a diversity of foods.
	Planktivore: Adults feed up in the water column by actively selecting plankton or sieving plankton from the water.
	Piscivore: Adults feed up in the water column. Fish make up the primary food of these fishes by volume.
	Surface-water
	Omnivore. Adults consume a variety of food organisms directly from the surface or from near-surface waters.
	Bottom-water
	Omnivore. Adults consume a variety of food organisms from directly on the bottom or disturb the bottom to obtain food actually located in bottom substrates.
Economic Guilds	Recreational
Species of fish that provide monetary input into the local economy through commercial fisheries, recreational/sport fisheries, or indirectly as important forage fish for species in the above fisheries.	Tailwater. Species that are actively sought after by recreational fishermen in the tailwater habitats of UMR pools.
	Boat: Species that are actively sought after by recreational fishermen in a variety of habitats in UMR pools that require access by boat.
	Ice. Species that are actively sought after by recreational fishermen through the ice.
	Shore. Species that are actively sought after by recreational fishermen from shore areas of UMR pools.
	Commercial
	Food: Species that are collected by commercial fishermen and sold as food.
	Bait: Species that are collected and sold as bait for recreational fishing.
	Minor: Species that are not caught in significant numbers by commercial fishing in the UMR pools of concern
	Forage
	Species of fish that in themselves are not sought after commercially or for recreation, but that provide food for those species that are.

Table 38. Predominant guild assignments for fish known or suspected to occur regularly in the UMR main channel ichthyoplankton drift.

Species	Guilds[a]	Selected references[a]
Scaphirhynchus platorynchus	Nonguarder litho-pelagophil; bottom omnivore; minor commercial (food)	Balon (1975); Held (1969); Becker (1983)
Polyodon spathula	Nonguarder litho-pelagophil; open water planktivore; minor commercial (food)	Purkett (1961); Becker (1983); Becker (1983)
Dorosoma cepedianum	Nonguarder litho-pelagophil; open water planktivore; forage	Balon (1975); Bodola (1966); Becker (1983); Miller (1960)
Hiodon alosoides	Nonguarder litho-pelagophil; open water omnivore; forage	Balon (1975); Becker (1983); Becker (1983)
H. tergisus	Nonguarder litho-pelagophil; open water omnivore; none	Balon (1975); Becker (1983); Becker (1983)
Cyprinus carpio	Nonguarder phytophil; bottom omnivore; commercial (food)	Balon (1975); Becker (1983); Rasmussen (1979)
Hybopsis storeriana	Nonguarder litho-pelagophil; omnivore; forage	Becker (1983); Becker (1983); Kinney (1954)
Notropis atherinoides	Nonguarder psammophil; open water omnivore, commercial (bait), forage	Balon (1975); Becker (1983); Becker (1983); Scott and Crossman (1973)
Carpiodes carpio	Nonguarder psammophil; bottom omnivore; commercial (food)	Becker (1983); Becker (1983); Rasmussen (1979)
C. cyprinus	Nonguarder psammophil; bottom omnivore; commercial (food)	Balon (1975); Harrison (1950); Rasmussen (1979)
C. velifer	Nonguarder psammophil; bottom omnivore; commercial (food)	Becker (1983); Harrison (1950); Rasmussen (1979)
Ictiobus bubalus	Nonguarder phytophil; bottom omnivore; commercial (food)	Becker (1983); McComish (1967); Rasmussen (1979)
I. cyprinellus	Nonguarder phytophil; bottom omnivore; commercial (food)	Balon (1975); Walburg and Nelson (1966); Rasmussen (1979)
Moxostoma macrolepidotum	Nonguarder lithophil; bottom omnivore; commercial (food)	Balon (1975); Bur (1976); Becker (1983)
Ictalurus punctatus	Guarder, nest-spawner speleophil; bottom omnivore, commercial (food); recreational (shore, boat)	Balon (1975); Finke (1964); Rasmussen (1979)
Pylodictis olivaris	Guarder, nest-spawner lithophil; bottom piscivore; commercial (food); recreational (shore, boat)	Balon (1975); Minckley and Deacon (1959); Becker (1983)
Morone chrysops	Nonguarder phyto-lithophil; surface omnivore, recreational (boat, tailwater, shore)	Balon (1975); McNaught and Hasler (1961); Rasmussen (1979)
M. mississippiensis	Nonguarder phyto-lithophil, open water omnivore, recreational (boat, tailwater)	Becker (1983), Becker (1983); Becker (1983)
Lepomis macrochirus	Guarder, nest-spawner lithophil, open water omnivore, recreational (boat, shore, ice)	Balon (1975); Carlander (1977); Rasmussen (1979)
Pomoxis annularis	Guarder, substrate chooser, phytophil; open water omnivore; recreational (boat, shore, ice)	Balon (1975); Hoopes (1960); Becker (1983)
P. nigromaculatus	Guarder, nest-spawner, phytophil, open water omnivore, recreational (boat, shore, ice)	Balon (1975); Becker (1983); Becker (1983)
Perca flavescens	Nonguarder phyto-lithophil; open water omnivore; recreational (boat, ice)	Balon (1975); Turner (1921); Becker (1983)
Percina caprodes	Nonguarder psammophil; bottom omnivore; forage	Balon (1975); Priegel (1969); Wright (1970)
Stizostedion canadense	Nonguarder lithophil, open water piscivore; recreationonel (boat, tailwater)	Balon (1975); Joy (1975), Becker (1983); Wright (1970)
S. vitreum	Nonguarder lithophil, open water piscivore; recreational (boat, tailwater)	Balon (1975); Scott and Crossman (1973); Becker (1983)
Aplodinotus grunniens	Nonguarder pelagophil, bottom omnivore; commercial (food)	Balon (1975); Couey (1935); Becker (1983)

[a] Reproductive guild, feeding guild, economic guild

5. RECOMMENDATION ON REPRESENTATIVE, IMPORTANT FISH SPECIES (RIFS) FOR FUTURE STUDY

Of the 27 taxa that occur regularly in ichthyoplankton drift of the main channel, eight can be justified for future study based on criteria of guild assignment, relative abundance, and the existing data base.

The eight species are gizzard shad, common carp, emerald shiner, channel catfish, white bass, black crappie, sauger, and freshwater drum. Five of these proposed RIFS are the most abundant species found in the ichthyoplankton drift of the UMR (Table 36). Considerable data exist on their spawning periods and the abiotic environmental parameters associated with their presence in the drift.

Gizzard shad and emerald shiners are important forage species. However, they differ in their diel drift periodicity and adult reproductive strategies. The common carp is a major commercial species and its larvae exhibit a strong tendency to drift. White bass larvae can be very abundant in ichthyoplankton samples collected in the main channel and remain very specific to the main channel as juveniles. The freshwater drum is the only truly pelagic spawner found in the UMR. Its eggs and protolarvae are buoyant and concentrate in large numbers above the locks and dams.

Analyses of the drift patterns of several other species are justified despite their observed lower densities in the drift. Black crappie mesolarvae demonstrate a strong diel drift pattern; although they are never predominant in samples, they occur with regularity. Larval sauger are specific to main channel bottom waters. After leaving their nest, young channel catfish prefer main channel bottom waters in riverine systems but are rarely collected in the 1/2-meter or 1-meter plankton nets commonly employed in drift studies. We believe, however, that this absence is simply a function of gear avoidance, not an indication of a lack of downstream transport or drift by these species. Both channel catfish and sauger represent major exploited fisheries in the region and deserve special evaluation if simply because of their economic value.

A similar argument could be made for study of three other species that are of considerable value in the region. These species are shovelnose sturgeon, paddlefish, and walleye. Although concentrated efforts have already been made to collect eggs and larvae of shovelnose sturgeon and paddlefish using specialized gear, no early life stages have been captured (Southall personal communication, Hurley personal communication). It is impractical to expend energy and resources to collect life stages that either do not occur in the drift or are simply too rare to be discerned.

Sampling efforts have also been undertaken to collect walleye eggs and larvae (Holzer personal communication, Gates personal communication). Most of the identified spawning areas have been in near-main channel backwater areas with flooded grasses, not in the main channel. Eggs, protolarvae, and mesolarvae have been collected in this type of habitat. Metalarvae are rarely collected in the study area of Pools 5 through 8 and are not present in the drift. The walleye, therefore, is not recommended as a RIFS. However, juvenile walleye inhabit main channel border habits and demonstrate diel movement patterns that might make them susceptible to downstream transport. Juveniles should be targeted for studies to examine adult movements.

It is appropriate to state at this time that the impacts of hydropower development on the recruitment of fish into the community must be viewed as a whole as well as from a species-specific mode. It is our belief that true long-term deviations in community structure cannot be properly evaluated using a species by species approach. Total drift and the environmental parameters that determine the drift density distribution over time must also be evaluated.

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6. LIFE HISTORY AND REPRODUCTIVE STRATEGY OF RIFS

The degree to which small-scale hydropower development on the UMR might affect recruitment of species that occur in the drift will depend heavily on the life history characteristics of each species. Knowledge of the time and duration of spawning is primary to any impact assessment since the proposed "run of the river" hydropower systems will vary seasonally in their alteration of near-dam flow characteristics. In addition, spawning location, reproductive strategies, and early-life history characteristics are closely correlated to the probability of impact.

This section presents relevant information on the distribution, abundance, and life histories of the most important fish species under consideration. These data have been summarized primarily from Scott and Crossman (1973), Becker (1983), Van Vooren (1983), Holland and Sylvester (1983a), Pflieger (1975), Holland and Huston (1983), and Balon (1975).

Gizzard Shad

The gizzard shad (*Dorosoma cepedianum*) is found throughout most of the eastern United States (Becker 1983). It is common in the Great Lakes drainage, the Mississippi Valley, and throughout the Missouri drainage (Scott and Crossman 1973). This species is abundant in all pools of the UMR (Van Vooren 1983).

Gizzard shad inhabit quiet waters that range from very clear to extremely turbid but they avoid high gradient streams. They prefer areas of high productivity and large permanent pools (Pflieger 1975).

Gizzard shad tend to travel in large schools, often near the surface. These fish are filter feeders with closely set gill rakers. However, they will graze on detritus on the bottom. They are important as forage fish, especially in winter for ducks and eagles, but have no other economic value (Scott and Crossman 1973).

Gizzard shad spawn in sloughs, ponds, lakes, large rivers, and protected bays (Jones et al. 1978). Spawning activity spans from early-April through May in Missouri (Pflieger 1975) at temperatures ranging from 17.2° to 22.8°C (Scott and Crossman 1973). Fecundity ranges from 211,380-543,910 and is considerably variable (Scott and Crossman 1973). Eggs are demersal and adhesive (Holland and Huston 1983). Incubation is 95 hours at about 17°C (Miller 1960). In Pool 7, larvae began to appear in the drift at 16°C (Holland and Sylvester 1983a). Larvae are found in all UMR habitats, but the greatest concentrations occur in backwaters (Holland et al. 1983). The gizzard shad is a litho-pelagophil reproductive strategist. Larvae become buoyant and are easily transported by currents (Balon 1975). Drifting larvae are twice as abundant in main channel surface waters at dusk than at any other time (Holland and Sylvester 1983a).

Common Carp

The carp (*Cyprinus carpio*) is indigenous to Europe and to temperate portions of Asia. It was successfully introduced into North America in 1877 and carp have spread throughout most stream systems of the United States. They prefer relatively warm waters of shallow, mud bottom lakes and larger streams. They are abundant in all pools of the UMR, and occur throughout the entire river (Van Vooren 1983).

Spawning occurs in rivers, lakes, marshes, forested swamps, ponds, and sheltered vegetated areas of streams from mid-May to early-August.

Fecundity ranges from 56,400 to 2.2 million (Swee and McCrimmon 1966). Eggs are adhesive and demersal. Incubation is 3-5 days at 29°C (Mansueti and Hardy 1967). In the UMR, larvae first appear in the drift in mid-May when temperatures reach about 18°C. Larvae demonstrate a strong drift pattern (Holland and Sylvester 1983a).

Emerald Shiner

Emerald shiners (*Notropis atherinoides*) occur throughout most of central North America from northwest Canada east to Lake Champlain, south to eastern Alabama and Texas (Becker 1983). This species is the most common minnow in the Missouri and Mississippi Rivers (Pflieger 1975). It is abundant in all pools and reaches of the UMR (Van Vooren 1983).

The emerald shiner lives in open channels of large, low to moderate gradient streams where there is noticeable current. In the UMR, emerald shiners are very common in main channel habitats and are most abundant in surface waters. Spawning occurs in shallow waters at about 22°C (Flittner 1964). Fecundity is estimated at 2,040 for a 75 mm TL female (Becker 1983). Eggs are adhesive and demersal. Incubation is from 24-32 hours (Becker 1983). Larvae appear in the drift by mid-June. As a nonguarding psammophil reproductive strategist, larvae are photophobic (Balon 1975) and are not common in main channel drift during the day (Holland and Sylvester 1983b). Densities increase significantly in main channel surface waters at dusk (Holland and Huston 1983).

Channel Catfish

The channel catfish (*Ictalurus punctatus*) is distributed throughout much of the eastern United States (Becker 1983). In the UMR, it is common in all pools (Van Vooren 1983). Channel catfish frequent channels of large rivers in areas that range from no current to swift current (Scott and Crossman 1973). Cool, clear, deep waters or muddy waters are common habitats (Scott and Crossman 1973). They are usually located on or near the bottom and are most active at dusk and dawn.

Channel catfish are nest spawning speleophils (Balon 1975). Fecundity is variable, ranging from 1,000-70,000 (Carlander 1953, Jearald and Brown 1971). Eggs are demersal and very adhesive. Spawning usually occurs between May and July; the optimum temperature is 26.7°C (Becker 1983). Incubation is from 5-10 days at 15°-27°C (Scott and Crossman 1973) and larvae have their full compliment of fins before the yolk is absorbed (Jones et al. 1978). Larvae are guarded by the male and travel in tight schools until they disperse as juveniles. Young are rarely collected in plankton nets, but are abundant in main channel trawl samples, particularly those taken at midnight (Holland and Sylvester 1983b).

White Bass

White bass (*Morone chrysops*) occur from the St. Lawrence River west to South Dakota and, south in the Ohio and Mississippi River drainages (Scott and Crossman 1973). In the UMR, this species is common in all pools and reaches (Van Vooren 1983). White bass often travel in schools and are surface feeders (Scott and Crossman 1973).

White bass spawn near the surface in shoal areas and spawning may extend from a 3-day period to as long as several weeks (Becker 1983). Water temperatures range from 12.8 to 26.1°C (Scott and Crossman 1973) with a peak at 16.9-22.6°C (Horrall 1962). Any rapid increase in water temperature during the spring triggers an increase in activity and shortens the spawning period (Becker 1983). Eggs are adhesive and demersal and there is an average of 565,000 eggs per female (Riggs 1955). Eggs hatch at 20.2°C in 45 hours from a Wisconsin lake (Horrall 1962). This species is a phyto-lithophil (Balon 1975) which implies that the larvae are closely associated with vegetation. Yolk-sac stages are uncommon in the drift. However, older larvae have been very abundant in the drift in side channel areas associated with flooded hardwoods (Holland et al. 1983) as well as common in drift from many of the pools discussed earlier.

Black Crappie

The black crappie (*Pomoxis nigromaculatus*) was originally restricted to freshwaters of eastern and central North America, but introductions have made its western limit difficult to define (Scott and Crossman 1973). Black crappies are common in all pools, but they are only occasionally to rarely collected in the lower reaches of the UMR. They are usually found in discrete, moderately large schools, commonly associated with abundant vegetation, rock structures, and gravel to muck bottoms.

Black crappie usually spawn in May and June (Becker 1983, Holland and Huston 1983) at temperatures of 18° to 20°C. Spawning usually occurs in water 254-610 mm deep (Scott and Crossman 1973) where the nest is swept out in sand or fine gravel (Becker 1983). The location is usually associated with vegetation. This phytophil reproductive strategist (Balon 1975) has adhesive, demersal eggs. The average female has 20,000-60,000 eggs (Eddy and Underhill 1974). Hatching time in the laboratory was 57.5 hours at 18.3°C (Merriner 1971). Larvae are abundant in backwaters, but demonstrate significant drift in the main channel at dusk (Holland and Sylvester 1983a).

Sauger

The sauger (*Stizostedion canadense*) is common in many of the major river systems in central North America. They are common in all 27 pools of the UMR (Van Vooren 1983). The species is more tolerant of silted bottoms and turbid waters than its congener, the walleye. Sauger prefer shallow, turbid lakes or large, turbid, slow-flowing rivers (Scott and Crossman 1973) and are particularly common in UMR tailwaters.

Spawning habitat appears to vary with location. In lakes, spawning takes place in shallow waters over sand or gravel (Scott and Crossman 1973). In the UMR, spawning occurs in main channel border areas (Pitlo, personal communication) and in tailwaters. This species is a lithophil reproductive strategist (Balon 1975). Eggs are initially adhesive, but later become nonadhesive and are demersal to semi-buoyant. Fecundity can range from 9,000 to 96,000 eggs per female (Scott and Crossman 1973). The incubation period is 21 days at 8.3°C (Nelson 1968). Larvae are highly photophobic and scatter quickly amongst bottom materials (Balon 1975). Typical ichthyoplankton sampling seldom picks up larvae.

Freshwater Drum

Freshwater drum (*Aplodinotus grunniens*) occur throughout the major river drainages of central North America. They inhabit large rivers, lakes, and impoundments (Becker 1983). This species prefers open turbid waters of warm sluggish lakes and streams. Freshwater drum are common to abundant in all pools and reaches of the UMR (Van Vooren 1983).

Spawning occurs pelagically in open waters, usually from May to the end of June at water temperatures of 19° to 22°C (Becker 1983). This pelagophil reproductive strategist (Balon 1975) has a highly pelagic egg and a buoyant yolk-sac stage larva. Fecundity varies greatly in this species, ranging from 34,000 to 850,000 eggs per female (Daiber 1953, Swedberg and Walburg 1970) and incubation is from 24-48 hours (Becker 1983). Eggs and larvae concentrate above locks and dams of the UMR. Densitites at such locations can be several fold those found elsewhere (Holland and Sylvester 1983a).

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7. BEHAVIOR OF RIFS IN RELATION TO OCCURRENCE IN DRIFT

Total Drift

Seasonal

The seasonal timing of peak ichthyoplankton drift in the river is directly related to the attainment of a certain minimum water temperature. In addition, drift appears to increase and decrease gradually or sharply over time as a function of the rate of increase of water temperature in the spring. Although river discharge may be of species-specific importance, it is not clearly correlated to changes in the total ichthyoplankton drift.

In nearly all cases where water temperature was reported, peak total ichthyoplankton densities occurred when temperatures were between 25°C and 30°C, after that densities decreased drastically (Figures 23-25). Drift densities peaked anywhere from early-June to early-July, but, in general, were greatest during the 2nd or 3rd week in June.

Although the ability to predict the seasonal timing of peak drift is important in an evaluation of possible hydropower impacts on recruitment, the ability to predict the variability of ichthyoplankton drift densities with time is equally important. It is not known whether the majority of the total drift occurs in a very short period of time as reported in Pool 14, 1976 (Figure 25) or over a more protracted season as reported in Pool 14, 1975 and Pool 7, 1981 (Figure 23). More complete knowledge of the distribution is critical to any impact and mitigation evaluations. In the years that water temperatures increased gradually to the critical minimum temperature and did not fluctuate noticeably, the ichthyoplankton density distribution was unimodal and the peak density could be easily predicted.

However, a predictive model of timing of peak density and distribution shape is beyond the scope of this contract and should be undertaken in the future.

Diel

Ichthyoplankton in the UMR, as in other rivers, demonstrate a distinct diel pattern of variation in drift. Holland and Sylvester (1983a) found that in main channel habitats of the UMR peak larval fish densities occurred at dusk (Figures 6, 7). However, Gale and Mohr (1978) found that, on the Susquehanna River, peak drift occurred between 2400 and 0300. Both studies found significant species-specific variations in drift patterns that influenced the overall diel periodicity. It is likely that differences in the ichthyoplankton found in the two rivers may account for the observed differences in the total diel drift patterns. Other reports of work on the UMR (referenced earlier) agree that drift is greatest at night and the primary pulse in drift occurs at dusk. These observed increases in ichthyoplankton densities are at least partially accounted for by diel variations in behavior and may not represent actual increases in the ichthyoplankton populations of the main channel. However, evaluations of diel ichthyoplankton density patterns suggest that, for several species there is significant transport from backwaters to the main channel (Nickum, personal communication).

Representative Important Fish Species

Gizzard shad

Gizzard shad spawn in low-current backwaters of the UMR. Since the eggs are very adhesive and demersal in nature, this behavior excludes the embryonic stage from occurrence in the drift. The larvae, however, exhibit a variety of behaviors that make them susceptible to movement by currents. Gizzard shad larvae are not photophobic (Balon 1975) and although they are slightly negatively buoyant, newly hatched larvae exhibit a consistent pattern of upward swimming and downward settling (Bodola 1966). After a short time, larvae incorporate horizontal swimming behavior into the upward-downward movement. In addition, gizzard shad are relatively poor swimmers for the first several weeks after hatching (Walburg 1976) and cannot maintain their position against current. The mesolarval stage is very abundant in the main channel drift. However, mesolarvae and larvae in general are extremely more abundant in backwaters than in the main channel (Figure 10). Protolarvae, particularly those with yolk present, seldom appear in the main channel drift. This is perhaps because of the backwater spawning location and length of time required for larvae to be transported from that location to the main channel. Juveniles exhibit a schooling behavior similar to the adults. It is unclear when this behavior first develops and how it might affect the susceptibility of a particular life stage to passive transport.

Larvae are seasonally present in the main channel drift of the UMR from early-June (22°C) to early-July (27°C) and first appear when water temperatures exceed 16°C (Holland and Sylvester 1983a). They demonstrate strong periodicity in diel drift and vertical distribution patterns (Storck et al. 1978, Mayhew 1974, Taber 1969, Holland and Sylvester 1983a). Larvae are generally found in surface waters during the day and disperse at night (Figure 7). Catch of larvae in main channel waters is largest at dusk; densities during all other periods of the day average 50% lower than at dusk.

Common carp

Common carp spawn in shallow backwater areas. The adhesive, demersal eggs are generally scattered over vegetation and are not normally a component of the drift. Newly hatched larvae have cement glands on their heads and remain attached to vegetation for the first few days (Balon 1975, Becker 1983). Therefore, yolk-sac larvae are rarely present in the drift. Larvae demonstrate no photophobic behavior. They usually remain associated with vegetation until they reach 76-102 mm in length (Sigler 1958).

Despite the apparent behavioral preference for littoral zones of the system, mesolarval carp are common in the ichthyoplankton drift in main channel waters. In the UMR, carp are present in the drift from early-June (22°C) through early-July (27°C). Occasionally, individuals are found in early spring when water temperatures are as low as 14°C. Larvae exhibit a strong diel variation in drift tendency and are very abundant in the main channel at dusk (Figure 7). Catches taken at that time can be twenty-fold that at midday. Densities at midnight are similar to those during the day. Because larvae do not exhibit photophobic behavior or strong vertical migration tendencies, their presence in the drift at dusk is probably a function of disorientation as light levels decrease.

Emerald shiner

Emerald shiners spawn at night in open waters at depths of 2-6 m over gravel shoals (Flittner 1964, Dobie et al. 1956). Spawning occurs in schools. The nonadhesive, demersal eggs are broadcast in the water column and settle to the bottom. Newly hatched larvae with yolk-sacs demonstrate a preference for bottom waters for 72-96 hours and have a swimming behavior. After yolk absorption, the free-swimming larvae are positively phototropic (Balon 1975, Flittner 1964) and occur in the upper 2 m of the water column. Older larvae form large schools (Flittner 1964), as do the juvenile and adults, and show a strong preference for surface waters. This positive phototropic behavior makes the larvae subject to downstream currents and explains their predominance in the ichthyoplankton drift of the main channel.

Larvae generally first appear in the drift when water temperatures reach 25°C or in late-June. As in many other species, the larvae demonstrate peak densities at dusk (Figure 7). This could be due to disorientation and a greater susceptibility to gear. However, it is more likely that feeding intensity increases at night with a break up of schooling behavior, as it does in adults (Raney 1969). Further conclusions on behavior exhibited by larvae that would affect occurrence in the drift are limited by inconsistent reports of their presence in the available literature. Most studies present data on minnows by family or genus, rarely by species.

Channel catfish

Channel catfish spawn in a variety of protected locations including weedy backwaters (Fish 1932) and under rock ledges (Harlan and Speaker 1956). In the river, spawning occurs primarily inside hollow objects or in undercuts in the bank near fairly swift waters (Farabee 1979). The eggs are deposited as a gelatinous mass (Saksena et al. 1961) in a definite nest (Scott and Crossman 1973). The eggs are, therefore, not a component of the drift. At hatching, larvae are guarded by the male and exhibit a strong schooling behavior (Becker 1983). They generally form a tight cluster on the bottom of the nest for 2 days after hatching (Becker 1983), but they remain associated with the nest for up to 7 days and are rare in the drift (Marzolf 1957). The school makes feeding excursions to the surface towards the end of this period. After leaving the nest, the school may remain intact for several weeks (Mansueti and Hardy 1967) then disperse. Catch of young-of-the-year channel catfish at a main channel border area were double that of side channel or slough stations (Van Vooren, 1982). Channel catfish juveniles are predominant in main channel waters in late summer to early fall (LGL 1981, Holland and Sylvester 1983b), but are rarely caught in ichthyoplankton drift samples.

Young have been collected in the main channel of the UMR as early as mid-June (24°C), but peak densities occur in late-June or early-July (Tables 2 and 20). By late-July or when young are about 17 mm total length, they are common in main channel waters and demonstrate strong diel variations in vertical distribution and catch. They appear to hug the bottom during the day and are only occasionally caught by bottom trawls. At midnight, the bottom catch increases significantly and young catfish are also caught in surface trawls. Because channel catfish demonstrate a noctural feeding behavior (Armstrong and Brown 1983), the increase in catch in bottom waters at night may indicate greater susceptibility to drifting as feeding occurs.

<u>White bass</u>

White bass spawn in shoal areas near the surface during the day (Farabee 1979, Scott and Crossman 1973). The demersal, adhesive eggs attach to gravel or to any other object in the spawning area and are not a component of the drift. At hatching, larvae remain in shallow waters

(Walburg 1976) and exhibit a strong vertical swimming behavior (Siefert et al. 1974). Although this swimming behavior would normally subject them to currents, perhaps the location of spawning sites and the preference for shallow waters explains why yolk-sac stages are rare in the drift. After about 4 days, a horizontal swimming position develops. Protolarvae and mesolarvae can be abundant in the drift in certain stretches of the river, particularly those downstream from side channels associated with flooded hardwoods (Holland et al. 1983). As larvae reach about 10 mm, they occur near the bottom (Walburg 1976). Juveniles school (Farabee 1979) but it is unclear how early this behavior develops or how it affects larval susceptibility to drifting.

Larvae are usually present in the drift during a relatively-defined, short period between mid-May and early-June. They first appear when water temperature reach 17°C. Little information is available on their diel periodicity. Juveniles exhibit a horizontal pattern of movement on and off dredgespoil sites over a 24-hour period; they are abundant at midnight and uncommon at other times. It is unclear whether this behavior subjects juveniles to consistent downstream transport that might make them susceptible to impacts of hydropower development.

Black crappie

The black crappie is a nest spawner that is adapted to reproducing on soft bottom substrates (Balon 1975, Scott and Crossman 1973). The eggs are adhesive and demersal in nature and do not become a part of the drift. The male guards the nest until the larvae begin to feed and disperse (Becker 1983). Yolk-sac larvae, therefore, are also rare in the drift. However, protolarvae (after yolk absorption) and mesolarvae may be common in the drift, but they are still twice as dense in the backwaters. Too little information is available on their phototrophic behavior or swimming characteristics to determine if these factors affect their presence in the drift. Metalarvae and juveniles are primarily restricted in distribution to backwaters. This suggests that the short period of drift is a dispersal behavior. Other studies have shown that larvae move from littoral to limnetic areas in May and early June in lakes (Faber 1967).

Larvae occur in the drift for a short period in May, generally when water temperatures are between 14°C and 16°C. A strong diel pattern of abundance occurs which varies between main channel and backwater habitats (Figure 7). During the day, larvae are about twice as abundant in backwaters than in the main channel. However, at dusk, densities drop in the backwaters and increase in the main channel. This suggests a strong pattern of drifting as light intensity decreases. At midnight, larvae are found only in main channel and backwater surface waters; by dawn the daytime distribution pattern has become re-established.

Sauger

Sauger spawn from late-April through early-May or when water temperatures are between 6.1°C and 11.7°C (Becker 1983). The exact spawning habitat of the sauger in the UMR is not definitely known (Farabee 1979) but this species may spawn in shallows near shoals and sand-gravel bars (Hubbs and Lagler 1964, Scott and Crossman 1973). Ripe females have been collected in the main channel in waters of 0.3-1.4 m over rock riprap (Gebken and Wright 1972). The eggs have adhesive membranes after water hardening (Nelson 1968), but later become nonadhesive (Scott and Crossman

1973). They are demersal to semi-buoyant and may occur in the drift near the bottom of the water column. Larvae demonstrate a highly photophobic behavior pattern (Balon 1975) and scatter and hide in the interstitial spaces of the substrate. This behavior suggests that they would be uncommon in the drift. They may occur in bottom waters, but no data on the diel periodicity of drift densities of this species are available for the UMR.

Freshwater drum

The freshwater drum is the only true pelagic spawner that occurs in the UMR. The eggs are semi-buoyant (Daiber 1953, Taber 1969) and are a predominant component of the ichthyoplankton drift. Because of their buoyant nature, the eggs are common in the main channel and become concentrated just above lock and dam structures (Holland and Sylvester 1983b). Yolk-sac larvae have large singular oil globules (Fuiman 1982) that keep them suspended in the water column. After absorption of the yolk-sac, larvae are no longer "held" at the surface and exhibit strong negative phototropism. However, larvae still demonstrate a strong preference for main channel waters throughout their development.

Eggs and larvae are present in the drift from mid-May through late-July. Eggs first appear when water temperatures reach about 19°C; larvae appear shortly afterwards (Figure 26). Peak larval drift occurs between 22° and 25°C. Freshwater drum show some vertical movement and significantly greater occurrence in samples at night (Holland and Sylvester 1983b). Catches from main channel bottom waters increase at dusk. This is followed by a significant decrease in catch at midnight. Increases in catch from main channel surface, main channel border, and backwater sites are slightly delayed and occur at midnight (Figure 7). This apparent increase in catch is in part due to decreased gear avoidance by larger larvae at night (Holland and Sylvester 1983b), but increases in densities up in the water column definitely do occur. Freshwater drum eggs and larval stages have a high probability of impact from hydropower development.

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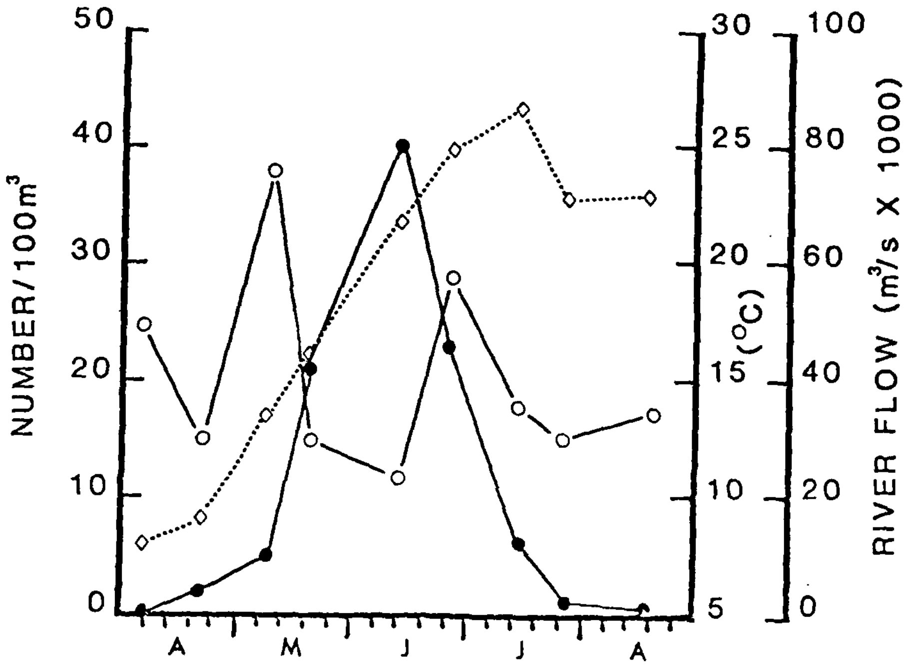

Fig. 23. Seasonal variation in ichthyoplankton drift (●) in relation to river discharge (o) and water temperature (◇), Pool 7, 1981.

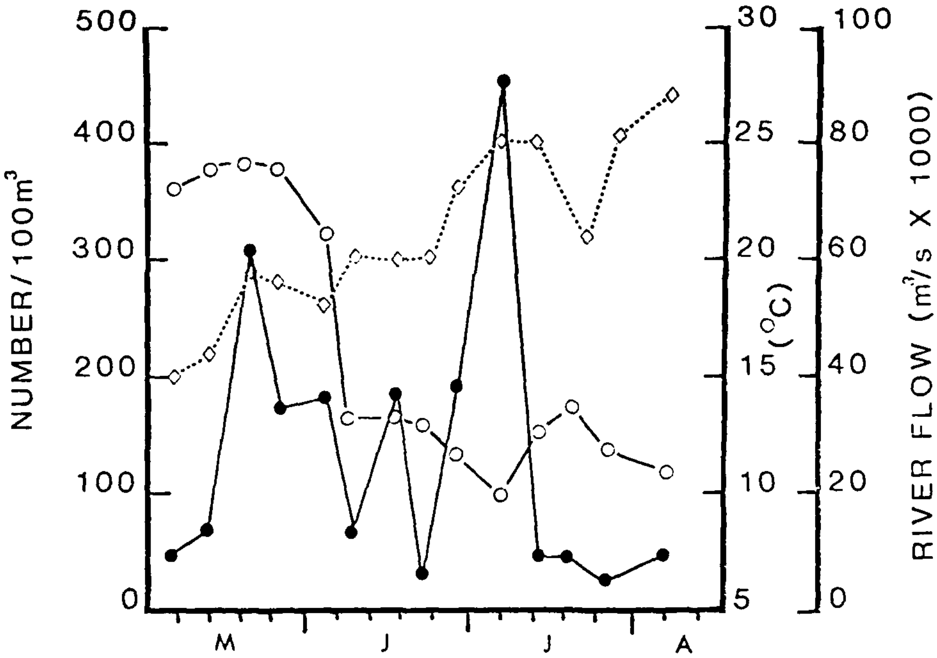

Fig. 24. Seasonal variation in ichthyoplankton drift (●) in relation to river discharge (o) and water temperature (◇), Pool 8, 1982.

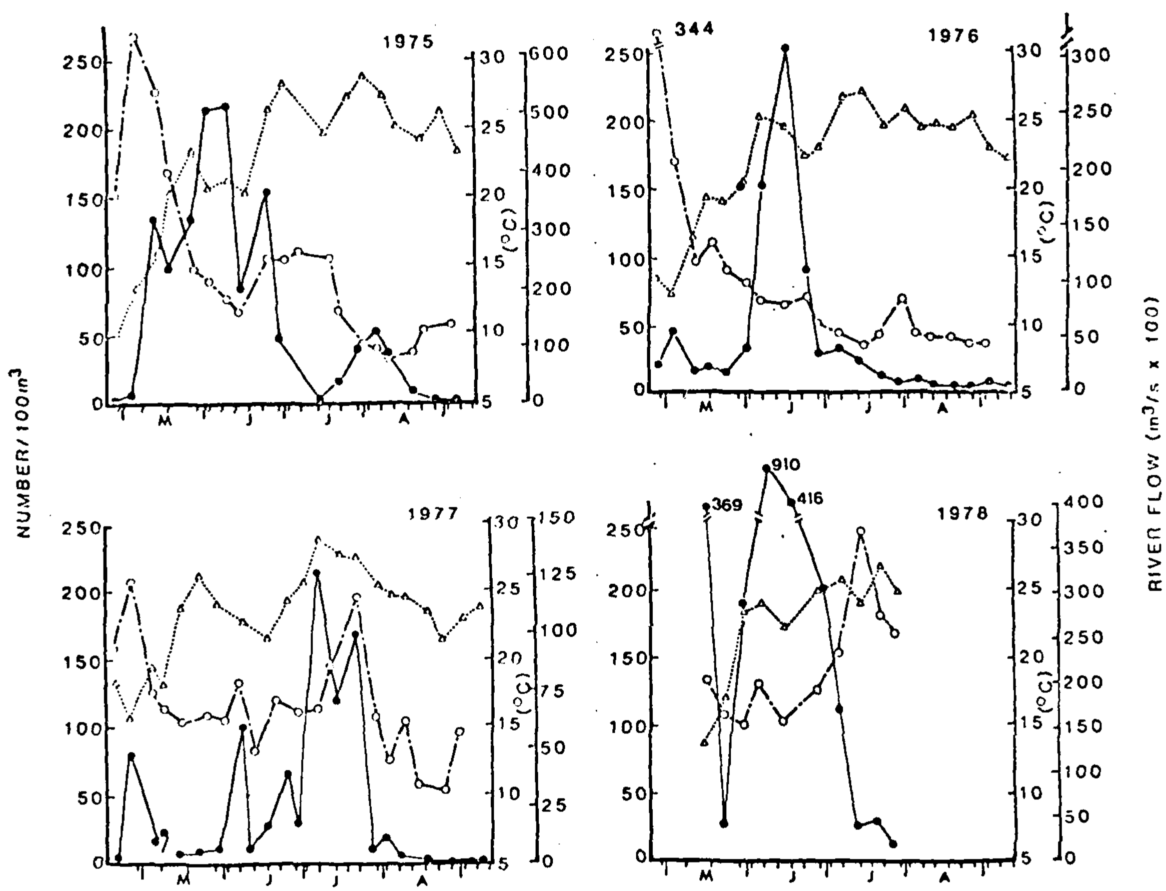

Fig. 25. Seasonal variation in ichthyoplankton drift (●) in relation to river discharge (o) and water temperature (Δ), Pool 14, 1975-1978.

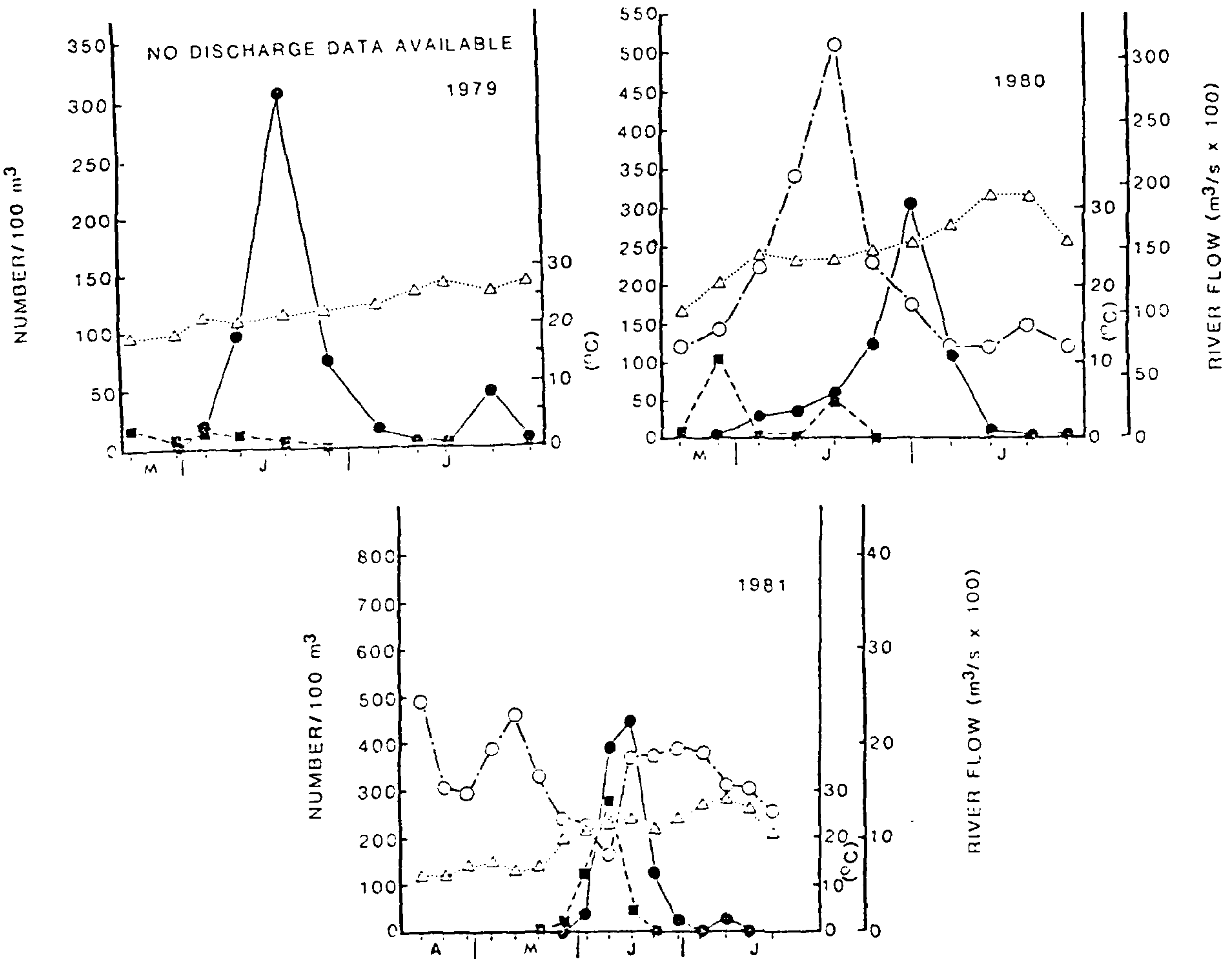

Fig. 26. Seasonal variation in freshwater drum egg (■) and larval (●) drift in relation to flow (o) and temperature (△), Pool 14, 1979-1981.

8. STATUS OF RIFS POPULATIONS

To properly evaluate our ability to discern impacts of hydropwer development over time on the selected test species, it is necessary first to determine if the present populations are stable or if other unrelated stresses are affecting or could affect the populations. A variety of sources, including unpublished sport and commercial catch statistics for the various pools were obtained and synthesized for comparison to historical data. This is not intended to be an exhaustive evaluation of long-term changes in fish populations of the UMR, but rather it is a brief discussion of trends. Harber et al. (1981) noted that "the lack of good commercial fishing records and the selectivity of the gear itself made determining the relative abundance of channel . . . catfish very difficult." A more comprehensive analysis of population trends of the RIFS will be required prior to final impact analysis.

Gizzard Shad

Insufficient data exist to permit a comprehensive evaluation of present trends in gizzard shad populations of the UMR. This species is not monitored by either the sport or commercial fisheries evaluation processes of the states. Gustafson et al. (1979), Pool 3, found no significant trend in abundance indices from 1973 through 1978. Gizzard shad have been listed as abundant by Rasmussen (1979) and by an update of that work (Van Vooren 1983).

Common Carp

For the 25-year period 1953-1977, Kline and Golden (1979) found the following overall trends in common carp populations:

Increase - Pools 5A, 7, 9, 10

Decrease - Pool 4

Wisconsin Department of Natural Resources' data for the period 1973-1982 show general trends of a decrease in pounds catch/effort (Table 39) in Pools 3 and 4, but relative stability in catch from Pools 5 through 10. Total catch during this period fluctuated, but seemed to decrease in Pools 4, 4A, 5, and 9 and increase in Pools 5A, 6, and 10 (Table 40). Gustafson et al. (1979), Pool 3, found no significant trend in abundance indices from 1973 through 1978. This species is listed as abundant by both Rasmussen (1979) and Van Vooren (1983).

Emerald Shiner

Insufficient data exist to permit an evaluation of present trends in emerald shiner populations of the UMR. This species is not monitored by either sport or commercial fisheries evaluation processes of the states. However, it is listed as abundant by both Rasmussen (1979) and Van Vooren (1983).

Channel Catfish

Although Kline and Golden (1979) reported an apparent trend toward over exploitation of the channel catfish fishery during the 25-year period (1953-1977), no statistical trend exists. However, a significant trend toward an increase in the population of Pool 4 and a decre e in the populations of Pools 3, 6, and 9 does exist.

Wisconsin Department of Natural Resources' data for the peri 1973-1982 show a general increase in catch/effort in Pool 4 and decreases in Pools 7, 8, 9, and 10 (Table 39). Total catches in Pools 7, 8, 9, and

10 appear to be decreasing, but are stable or increasing in other pools (Table 40).

White Bass

Creel census estimates for the study area indicate that the catch/man-hour fluctuates from year to year (Tables 41-44). However, overharvest does not appear to be a problem (Farabee 1979). Insufficient catch statistics exist to properly evaluate trends in the population. However, in Pool 3, Gustafson et al. (1979) found no significant trend in abundance indicies from 1973 through 1978. This species is listed as common by Van Vooren (1983).

Black Crappie

Estimates of catch/man-hour of crappie fluctuate from year to year (Tables 40-44). This is expected since year classes of black crappie normally vary considerably, as do other nest building species that utilize shallow areas for spawning. Short-term variations in environmental conditions affect these habitats more than limnetic habitats. No consistent pattern of increase or decrease in the populations can be identified based on the available data.

Sauger

Catch of sauger/man-hour increased steadily from 1967 through 1973 in Pool 7 (Tables 41, 42). Catch/man-hour was relatively stable in Pools 8 and 9 between 1971 and 1973 (Tables 43, 44). Farabee (1979) found that sauger were becoming an increasingly important sport species based on creel surveys for the period 1962 through 1973 (Nord 1964, Wright 1970, Fleener 1975). The populations appeared to remain fairly stable between 1976 and 1979 (Table 45).

Freshwater Drum

Total harvest of freshwater drum and catch/effort (Tables 41-44) remained fairly constant in the sport catch between 1962 and 1973 (Nord 1964, Wright 1970, Fleener 1975). Kline and Golden (1979) found trends in the commercial catch for the period 1953-1977:

Increase - Pools 5A, 8, 9, 10

Decrease - Pools 4, 5

Over the last 10 years, the total catch appears to have increased in Pools 4 and 5 and remained fairly constant in Pools 6, 7, 8, 9, and 10 (Table 40). Catch/effort has decreased consistently only in Pools 5A, 6, and 7 (Table 39).

Known Stressors

Adult fish populations in the UMR are already subjected to a variety of stresses. The major stressors include commercial and sport fishing, heavy metal and pesticide contamination, loss of spawning and nursery habitats due to sedimentation and vegetation growth, and unknown impacts of commercial navigation. An accurate picture of the effects of any of these stressors on long-term population trends is unavailable but certain data are available to indicate which stresses may act most heavily on each RIFS. Hydropower may simply add linearly to the present stress load of RIFS populations. However, many of the above stressors are highly interrelated and, however, it is more likely that all stressors act synergistically.

Commercial navigation is one of the main suspected stressors of fish populations in the UMR. Specifically, fish may be effected by the resultant changes in flow patterns, channel morphology, water quality, sediment transport, and ice cover (ERT 1979). The actual construction of the navigation system has had the most significant impact on the original riverine characteristics. The dams have produced an environment dominated by lentic, pool dynamics. Channelization has resulted in significant alteration in the original chemical/physical characteristics of the system. Simons et al. (1981) and Lubinski et al. (1981) summarize the extent and nature of the ranges in physical and chemical dynamics of the system.

An extensive amount of literature addresses suspected or known impacts of navigation on the aquatic community of the UMR (e.g., GREAT I 1979, Harber et al. 1981, Kennedy et al. 1981, Lubinski et al. 1981, Rasmussen and Harber 1981, Schnick et al. 1982). Significant information has been compiled to indicate that operation and maintenance activities such as clearing and snagging, dredging, dredespoil deposition, bank stabilization, and leveeing may stress the environment and directly or indirectly the fisheries. Adverse effects of boat traffic are also of concern. Bank erosion and increased sediment transport into backwaters has been documented (Simons et al. 1981). The potential for altered recruitment into the fisheries of the UMR from navigation related water drawdown has been documented (Holland and Sylvester 1983a). Increased mortality in freshwater drum eggs and changes in ichthyoplankton distribution have been shown to occur in the main channel with passage of commercial vessels (Holland and Sylvester 1983b). It appears that nearly all components of the biological community are affected by the physical and chemical changes caused by barge traffic (UMRBC 1981). Although the magnitude of all of these impacts have not been determined, significant evidence exists to support concerns that increases in navigation-related activities on the river will adversely effect the quality of the ecosystem.

Evaluation of some of the potential impacts of navigation on fishes of the UMR was undertaken during the Master Plan process. Kennedy et al. (1981) evaluated potential effects on fish early life stages. Most of the RIFS selected to evaluate hydropower development also were selected as indicator species for evaluation of navigation impacts. Freshwater drum, gizzard shad, and emerald shiners were thought most susceptible to direct effects of navigation. Channel catfish young may be effected minimally. However, concerns over major data gaps were voiced. Wave wash/drawdown impacts and direct effects of hull and propeller impacts were indicated for sauger. Little specific data on navigation impacts on white bass were found. Habitat loss due to increased sedimentation might significantly alter success of species which spawn in backwaters (e.g., carp, black crappie). Kennedy et al. (1981) found that 15 major data gaps exist that limit further analyses of navigation impacts. Rassmussen and Harber (1981) found that navigation may significantly affect quality spawning habitat for channel catfish.

Organic and inorganic contaminants from domestic waste, urban runoff, industrial effluents, and agricultural runoff into the UMR have created a signficant problem in recent years (Sprafka 1981, Wiener et al. 1984). Although the distribution and biological effects of some pollutants have been studied in some depth, little is known about many more.

Metals of major concern include cadmium, mercury, lead, cyanide, zinc, copper, nickel, and arsenic. Most of these metals are toxic nonessential elements; some like zinc and copper are essential elements yet toxic at high concentrations (Forstner and Wittmann 1979). Heavy metals are not biodegradable and once in an aquatic system are usually adsorbed onto fine sediments and organic matter (Forstner and Wittman 1979). Even if associated with sediments, many metals possess the potential for change in chemical reactions or biological interactions sometimes to a more toxic or available compound (Sprafka 1981). Some documented effects of certain metals on fish include death, reproductive failure, reduced growth, weight loss, impaired swimming, and other behavioral changes (Jackson et al. 1981, Sprafka 1981).

Many organic pollutants are of concern because of their environmentally persistant nature. Organochlorines, pentachlorophenol (PAP), phenols, polycyclic aromatic hydrocarbons (PAH's) and polychlorinated biphenyls (PCB's) are some organic pollutants (Jackson et al. 1981). In addition to resistance to degradation, these compounds tend to bioaccumulate within the aquatic food chain (Brown 1978). They adsorb to fine sediments as metals do and can be adsorbed directly, or ingested by organisms. Organochlorines are reported to disrupt transmission of nerve impulses, however, the exact method of toxicity of most organic pollutants are unknown (Jackson et al. 1981).

Harmful levels of contaminants determined in the laboratory are often based on acute toxicity tests under very specific conditions and cannot be directly compared to levels *in situ*. Availability and effects of metals and pollutants depends on environmental factors such as pH, alkalinity, hardness, oxidation-reduction potential of the sediments, nature of the sediments and organic matter, and hydrology factors (Khalid et al. 1977, Jackson et al. 1981). Little information is available on sublethal effects of contaminants or on the cumulative, synergistic, or antagonistic effects of combinations of the compounds as they are found in aquatic systems (Jackson et al. 1981).

Of the RIFS in this report, the bottom feeders or those that feed on organisms which spend time on the bottom have the greatest probability of stress from metal contaminants because of the adsorption of these elements to sediments. Organic pollutants that bioaccumulate may affect populations of top predators more than lower level consumers.

Commercial and sport harvests of fishes are known stressors on populations. However, harvests are strictly regulated to maintain a sustained yield. There is little evidence that significant overharvest of species is occurring in the UMR. However, certain populations may be currently harvested at their maximum sustainable yield (e.g. walleye). The addition of another stressor to these populations may have significant impacts on harvest.

Loss of aquatic habitat in the UMR is another stressor that will affect the RIFS. Loss of backwater habitats because of upland erosion or navigation activities affects available spawning-nursery habitats and feeding areas. Gizzard shad, common carp, and black crappie may be most significantly stressed because of their reproductive strategies. Each relies heavily on backwaters as spawning and nursery habitats.

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Table 39. Available commercial catch statistics (lb/unit effort) of RIFS for 1973 through 1982, Wisconsin Department of Natural Resources

Species	Pool	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Common carp	3	4.87	-	-	-	-	0.15	0.09	0.05	0.50	0.08
	3A	-	1.86	0.04	6.61	0.34	4.53	1.01	-	0.10	0.45
	4	0.22	0.30	0.26	0.89	0.25	0.09	0.13	0.31	0.00	0.03
	4A	0.42	0.18	0.72	1.40	0.58	0.18	0.30	0.30	0.27	0.50
	5	0.36	0.27	0.26	0.45	0.25	0.20	0.15	0.23	0.18	8.32
	5A	0.33	0.20	0.92	0.21	0.19	0.18	0.16	0.21	0.20	0.55
	6	0.28	0.14	0.31	0.35	0.09	0.11	0.14	0.15	0.12	0.09
	7	0.35	0.43	0.34	0.20	0.24	0.22	0.13	0.19	0.16	0.21
	8	0.44	0.36	0.35	0.38	0.25	0.38	0.28	0.26	0.28	0.19
	9	0.51	0.87	0.66	0.46	0.18	0.36	0.73	0.23	0.37	0.44
	10	0.08	0.10	0.06	0.10	0.08	0.08	0.12	0.11	0.15	0.09
Channel catfish	3	0.01	-	-	-	-	<0.01	<0.01	-	<0.01	<0.01
	3A	-	<0.01	<0.01	ND	<0.01	<0.01	ND	<0.01	<0.01	0.01
	4	0.05	0.08	0.13	8.24	0.06	0.17	0.52	18.99	0.23	0.16
	4A	0.01	<0.01	0.03	0.02	0.01	0.01	0.03	0.03	0.06	0.06
	5	0.14	0.05	0.02	0.05	0.03	0.04	0.07	0.04	0.02	0.84
	5A	0.03	0.03	0.03	0.02	0.02	0.01	<0.01	0.01	0.01	0.02
	6	0.04	0.01	0.03	0.01	0.05	0.03	0.02	0.02	0.04	0.02
	7	0.09	0.14	0.22	0.04	0.03	0.04	0.04	0.07	0.04	0.04
	8	0.12	0.12	0.14	0.12	0.04	0.06	0.04	0.04	0.04	0.02
	9	0.08	0.10	0.14	0.05	0.05	0.05	0.03	0.04	0.03	0.03
	10	0.06	0.11	0.13	0.05	0.04	0.06	0.04	0.03	0.03	0.01
Freshwater drum	3	0.02	-	-	-	-	<0.01	ND	ND	<0.01	ND
	3A	-	0.04	ND	0.03	<0.01	0.01	ND	-	<0.01	0.04
	4	0.02	0.02	0.01	0.53	<0.01	0.01	ND	ND	0.02	0.38
	4A	0.0	0.01	0.19	0.03	0.01	0.08	0.01	0.01	0.18	0.04
	5	0.12	0.15	0.01	0.08	0.01	0.02	0.05	0.06	<0.01	12.04
	5A	0.25	0.07	0.04	0.01	0.03	<0.01	<0.01	<0.01	0.02	0.03
	6	0.06	0.01	0.09	0.02	0.01	0.01	<0.01	0.01	0.01	<0.01
	7	0.11	0.09	0.17	0.02	0.02	0.03	0.02	0.04	0.03	0.04
	8	0.19	0.06	0.07	0.11	0.18	0.16	0.07	0.13	0.24	0.07
	9	0.20	0.34	0.24	0.17	0.09	0.10	0.35	0.08	0.17	0.18
	10	0.02	0.03	0.02	0.04	0.03	0.03	0.03	0.02	0.04	0.01

Table 40. Available commercial catch statistics (lbs/year) of RIFS for 1973 through 1982, Wisconsin Department of Natural Resources

Species	Pool	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Common carp	3	302,005	--	--	--	--	13,050	5,290	5,300	60,303	8,555
	3A	--	200,118	2,452	185,050	45,648	172,035	6,075	--	17,291	60,021
	4	23,470	46,455	18,473	1,045	43,305	3,176	656	89	9,107	1,460
	4A	1,337,086	965,739	425,261	961,826	382,913	122,349	98,544	130,509	81,425	109,054
	5	28,195	21,742	104,513	160,338	122,717	41,738	15,100	37,456	115,059	43,067
	5A	26,429	29,295	98,791	30,981	31,677	86,762	63,622	91,865	79,912	87,178
	6	38,052	16,036	10,890	37,314	12,253	55,305	71,306	68,125	26,846	61,094
	7	145,312	180,693	129,166	255,970	250,219	174,345	193,386	124,791	195,144	123,190
	8	410,838	402,221	385,251	559,351	551,862	616,091	406,548	611,121	485,071	445,569
	9	625,817	808,428	411,025	429,606	185,419	338,860	444,560	145,396	275,749	281,223
	10	63,227	51,710	28,922	55,339	70,205	62,491	116,211	105,148	176,720	131,887
Price ($/lb)		0.045	0.05	0.055	0.065	0.06	0.07	0.07	0.07	0.08	0.07
Channel catfish	3	545	--	--	--	--	47	34	166	246	332
	3A	--	23	36	ND	96	149	ND	--	259	1,001
	4	5,645	13,053	9,223	9,668	10,100	5,771	2,717	5,508	10,334	7,494
	4A	17,752	15,250	18,673	12,112	9,828	9,323	8,505	13,220	17,621	13,173
	5	11,008	4,363	9,143	19,114	16,250	8,630	7,419	6,301	13,334	4,342
	5A	2,695	4,547	2,814	2,912	2,629	4,382	842	3,871	2,573	2,998
	6	5,101	823	940	1,283	6,102	17,363	8,029	7,583	10,466	14,138
	7	37,601	60,749	83,015	56,212	32,421	31,013	39,227	48,455	44,436	22,261
	8	115,699	130,112	149,455	182,479	92,181	90,442	64,038	83,429	66,845	53,723
	9	94,903	98,102	84,377	48,593	48,133	49,304	21,086	23,776	20,077	16,538
	10	48,323	56,280	60,368	30,043	33,283	44,739	34,499	27,856	29,799	21,074
Price ($/lb)		0.40	0.355	0.365	0.44	0.44	0.45	0.525	0.55	0.605	0.565
Freshwater drum	3	939	--	--	--	--	13	ND	ND	435	ND
	3A	--	875	ND	845	10	350	ND	--	13	4,828
	4	1,672	2,760	1,004	622	657	200	ND	ND	806	18,276
	4A	60,115	55,018	113,305	22,461	4,951	50,273	3,199	5,902	54,356	9,385
	5	9,817	11,715	5,343	27,725	2,888	3,557	4,827	10,242	2,776	62,329
	5A	20,203	9,616	4,519	1,156	5,020	1,532	1,643	2,192	7,510	4,856
	6	8,272	1,289	3,250	2,081	1,136	5,993	2,264	3,047	2,111	2,622
	7	46,356	37,875	66,183	29,658	22,175	22,455	28,058	24,468	37,786	21,948
	8	181,328	68,145	79,130	163,232	395,276	255,997	105,019	298,802	408,014	167,462
	9	248,643	321,738	151,480	155,840	86,351	96,816	214,972	51,451	123,816	114,848
	10	12,786	14,516	9,537	20,262	23,151	22,056	27,492	17,798	42,012	10,845
Price ($/lb)		0.08	0.085	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10

Table 41. Available creel census estimates of catch/man hr. of RIFS for Pool 7, spring 1967-1970 and fall 1971-1973, Wisconsin Department of Natural Resources. Numbers in parentheses equal total number of fish.

Species	1967	1968	1969	1970	1971	1972	1973
Common carp	0.0027 (7)	0.0003 (1)	0.0027 (3)	---	---	---	0.0018 (2)
Channel catfish	0.0015 (4)	0.0003 (1)	---	---	0.0008 (1)	---	---
White bass	0.0225 (59)	0.0036 (13)	0.1837 (203)	0.0095 (15)	0.0856 (110)	0.0223 (34)	0.0018 (2)
Sauger	0.0563 (148)	0.0905 (326)	0.1873 (207)	0.3687 (58)	0.7856 (1,010)	0.7012 (1,070)	0.6980 (771)
Black crappie	0.5863 (1,540)	0.1412 (509)	0.0090 (10)	0.0013 (2)*	0.0124 (16)	0.0098 (15)	0.0272 (30)
Freshwater Drum	0.0023 (6)	0.0006 (2)	0.0009 (1)	---	0.0117 (15)	0.0033 (5)	0.0063 (7)

* Presented as "crappie" in Wisconsin Department of Natural Resources' data.

Table 42. Available 12-month creel census estimates of catch/man hr. of RIFS for Pool 7, Wisconsin Department of Natural Resources

Species	1962-1963		1967-1968		1972-1973	
Common carp	0.0012	(13)	0.0010	(20)	0.0009	(7)
Channel catfish	0.0062	(70)	0.0135	(257)	0.0135	(101)
White bass	0.0162	(182)	0.0344	(654)	0.0562	(419)
Black crappie	0.1894	(2,127)	0.1976	(3,760)	0.1282	(956)
Sauger	0.0395	(444)	0.0627	(1,193)	0.0998	(744)
Freshwater drum	0.0209	(235)	0.0174	(332)	0.0350	(261)

Table 43. Available creel census estimates of catch/man hr. of RIFS for Pool 8, fall 1971-1973, Wisconsin Department of Natural Resources

Species	1971		1972		1973	
Common carp	0.0007	(1)	0.0011	(2)	---	
Channel catfish	0.0020	(3)	0.0017	(3)	0.0050	(9)
White bass	0.1214	(181)	0.0115	(20)	0.0176	(32)
Black crappie	0.0047	(7)	0.0109	(19)	0.0160	(29)
Sauger	0.6325	(943)	0.6919	(1,205)	0.5813	(1,055)
Freshwater drum	0.0054	(8)	0.0092	(16)	0.0066	(12)

Table 44. Available creel census estimates of catch/man hr. of RIFS for Pool 9, fall 1971-1973, Wisconsin Department of Natural Resources

Species	1971		1972		1973	
Common carp	0.0018	(6)	---		---	
Channel catfish	0.0037	(12)	0.0004	(1)	0.0014	(3)
White bass	0.1123	(365)	0.0170	(45)	0.0078	(17)
Black crappie	0.0104	(34)	0.0008	(2)	0.0050	(11)
Sauger	0.5993	(1,948)	0.8866	(2,341)	0.5382	(1,177)
Freshwater drum	0.0079	(25)	0.0080	(21)	0.0073	(16)

Table 45. Creel survey of sauger in Pools 7, 8, and 9 from 1976 through 1979, Wisconsin Department of Natural Resources

Pool	Spring 1976	Fall 1976	Spring 1978	Fall 1978	Spring 1979
7	0.136	0.563	0.202	0.295	0.538
8	0.136	0.684	0.333	0.236	0.333
9	0/167	0.391	0.347	0.460	0.247

9. EVALUATION OF THE IMPORTANCE OF ICHTHYOPLANKTON MOVEMENT THROUGH DAMS TO RIFS POPULATIONS IN THE UMR

Calculation of drift distances, the number of dams an egg or larva might pass through, and an evaluation of the importance of this movement to the RIFS population would be simplified if individuals drifted downstream uniformly. However, larvae may not move in a simple relationship with the surrounding water mass (Wallace 1978). A number of factors influence the proportion of the eggs or larvae of a species that may drift through a dam. Reproductive strategies, developmental changes in larval behavior patterns, and the hydrologic characteristics of the system are factors that in themselves or in combination complicate the analysis.

The behavior of larval fishes in the main channel influences drift distances. Starnes et al. (1983) clearly demonstrated that white bass could resist downstream transport even in a system with a short hydraulic-transport time by means of behavioral adaption. Wallace (1978) showed that the behavioral pattern of vertical migration could couple with hydrologic characteristics of a system to "hold" larvae in an area longer than would be predicted based on the system's hydraulic-transport time. In the UMR, similar situations presumably occur. Changes in the vertical position of larvae in the water column over a 24-hour period or movement of larvae into eddy areas could significantly alter the accuracy of hydropower impact accessment based on present available data.

Nearly 100% of the emerald shiner population (from egg to adult) inhabits main channel waters. Eggs are demersal and uncommon in the drift, but the majority of the larvae are in the main channel drift and are highly susceptible to transport through at least one dam. Occurrence in the drift probably becomes minimal as soon as schooling behavior develops. The time required for this behavior to develop is unknown and, therefore, calculation of possible drift distances is difficult. However, a high percentage of the population probably passes through dams.

Nearly all freshwater drum eggs, protolarvae, and mesolarvae occur in the main channel. The eggs require from 24 to 48 hours to hatch (Becker 1983) and can be transported as far as 30 to 70 miles downstream. However, many are caught in eddies, concentrated in the impounded waters above dams, or transported into backwaters, and may never drift out of the pool in which they were spawned. Regardless, it appears that the vast majority of freshwater drum eggs and larvae have a high probability of being transported through at least one dam.

Information on the drift of sauger eggs and larvae is limited, but adults do exhibit upstream movements during spawning which suggests that some sort of cycle exists. Spawning occurs in the main channel, but the eggs are not pelagic like those of the freshwater drum. Larvae are photophobic and scatter into the rubble of the spawning site. Few larvae are collected in drift samples. The behavior of sauger suggests that drift is not important, however, sampling efforts have not been sufficient to judge the actual importance of drift to the population.

Common carp and black crappie are backwater spawners. As such, the eggs and yolk-sac larvae are rarely components of ichthyoplankton drift. In later protolarval and early mesolarval stages, these species exhibit strong vertical movement patterns and are abundant in the drift. However, densities of these species in the main channel appear to be fractions of those found in backwaters. Metalarvae and juveniles are nearly always found in lentic areas and, therefore, not likely to be directly influence by operation of the hydropower unit. Since individuals of these species collected in the drift are often nearly all uniform in size and presumably age, the duration of susceptibility to drift may be short. Impacts of passage through dams might be greatest when backwater areas are located proximally to the units. Recent studies suggest that large numbers of larvae are transported out of backwaters (Nickum, personal communication).

Gizzard shad is similar to common carp and black crappie in that this species spawns in backwaters, its eggs and protolarval are rare, but mesolarvae are very abundant in main channel ichthyoplankton drift, and the drifting component appears to be only a fraction of the total population of that stage. This species differs, however, in that the juvenile stage is often more abundant in lotic than lentic waters. Since gizzard shad larvae are more surface oriented, they may be more susceptible to downstream transport and impacts of passage through hydropower units than common carp or black crappie.

At least one stage of larval white bass is more abundant in the main channel than in any other habitat (Figures 8-10). Juveniles are also common in the main channel. Drift distances may be significant, but as suggested by Starnes et al. (1983) white bass may have retarded downstream movement because of behavioral adaptation. No actual study of the numbers of larvae which pass through dams is available for the UMR.

Channel catfish are uncommon in ichthyoplankton drift samples. Eggs are spawned in nests and early developmental stages are guarded by the male. As the young develop, however, they are most abundant in main channel waters. They appear to migrate vertically up into the water column at night, but during the day remain very close to the bottom. Ichthyoplankton studies rarely find this species in the drift. However, the 1/2-m or 1-m plankton nets with .505 mm-mesh that are commonly used to collect drift may not be the proper gear to determine if channel catfish have significant drift patterns. Armstrong and Brown (1983) used gear with a much larger mesh size when they demonstrated that young of this species drifted significantly in the Illinois River. The relative importance of drift through dams may be greater than indicated by presently available ichthyoplankton drift data.

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10. EVALUATION OF ASSESSMENT APPROACHES AND RECOMMENDATIONS

Mode of Action

Hydropower development on the upper Mississippi River will affect survival of ichthyoplankton primarily during operational phases. Construction phases should have little impact on drifting eggs and larvae. During operation, hydropower units will cause changes in the hydrologic character of the lower pool and tailwater regions, alterations in present pathways through dams, possible entrainment of fish, and changes in physical stress as individuals pass through turbines (Table 46). The impacts of these actions must be viewed from both organismal and population approaches (Horst 1975).

The primary effects of hydropower development (Table 46) are most reasonably assessed at the individual level. Changed patterns of dam gate operation may reduce ichthyoplankton access to present sites of transport through the dam and force an unknown number of individuals through the hydropower unit. Entrainment of individuals can occur, as can direct impingement. Eggs and larvae transported through the unit be subjected to greater shear forces, more-rapid pressure changes, and accelerative and decelerative forces. The primary effects of these actions may be disorientation, sublethal injury, or immediate mortality of the ichthyoplankton. Overall, changes in percent mortality may occur because of severe physical damage or because of increased predation on disoriented or sublethally injured individuals. Early growth may be reduced because of stress or physical damage. In addition, the hydrologic characteristics of lower-pool impounded waters and of tailwaters may vary from the present status quo. The numbers of

Table 46. Impacts of hydropower development on ichthyoplankton of the upper Mississippi River - causes and effects.

Source	Mode of action	Primary effects	Secondary effects
Hydropower plant operation	--change of pattern and current velocity and direction	--changes in the numbers of ichthyoplankton going over dam	--increased mortality
	--physical barrier to downstream movement along present pathways through	--disorientation	--delayed mortality
	--entrainment of fish	--sublethal damage	--increased predation
	--physical stress of turbine passage	--immediate mortality	--decreased growth
	--direct impingement		--reduced forage base
	--shear forces		--reduced population levels
	--pressure changes		
	--accelerative and deaccelerative forces		

drifting eggs and larvae that would be transported through either the hydropower unit or the dam gates might change because of alterations in current and velocity patterns. Survivability of eggs and larvae may also vary in the tailwaters because of the changed hydrology.

Once the total probability of mortality associated with the operation of the hydropower unit has been determined then the importance of that increase in mortality to the entire population must be evaluated. The impact of hydropower-related mortality as a portion of total mortality during early fish development must be translated into some change in adult numbers to be significant to the long range "health" of the population. However, significantly reduced numbers of larvae or juveniles may also translate into a reduce forage base for other populations--a community problem.

There are a variety of specific parameters and units of measurement that are appropriate for the assessment of hydropower impact on fish populations. Primary among these is the density of organisms at the intake of the hydropower unit (larvae or eggs/100 m^3 of water). If coupled with a mortality factor, this parameter can provide total number of ichthyoplankton lost because of hydropower unit operation. Mortality of these organisms due to passage through the unit (M_H) can be represented as

$$M_H = L_N - L_{Ho}$$

where L_N = the percentage of live ichthyoplankton in nature or prior to passage through the hydropower unit and L_{Ho} = the percentage of live ichthyoplankton immediately after passage. Delayed mortality after certain time intervals post-passage can be build into the model as follows:

$$M = L_N - L_{Ho} - L_{H1} - L_{H2} - \ldots L_{Hi}$$

Immediate mortality can be determined by observation of ichthyoplankton upon passage through the unit. Delayed mortality or disorientation must be evaluated by holding a sample.

As in power plant entrainment (Horst 1975), the mean value of mortality and variability in mortality may be high. In addition, precision of visual determinations of mortality may be very low, particularly in the highly productive, turbid waters of the upper Mississippi River. It may be most practical to assume total mortality of ichthyoplankters passing through the hydropower unit as a worse-case situation. Should that mortality translate into unacceptable adult population reductions, then further mortality assessment may be necessary.

Several methods can be used to evaluate the importance of the estimated mortality of ichthyoplankton to the adult population. These include (1) modeling of the population dynamics as a variation of the life table approach (Leslie 1945), (2) use of stock and recruitment functions (Ricker 1958), and (3) an equivalent adult method. The life table approach requires age specific mortalities and fecundities. Stock-recruitment models require a time series of both stock and recruitment estimates over a wide range of stocks and recruits. None of these data are particularly easy to obtain for riverine populations of fishes. An equivalent adult method, in its simplest form, assumes that if a population is in equilibrium, the fecundity produced by a breeding pair will result in two breeding adults (Horst 1975) or:

$$2 = S \times F$$

where S = survival from egg to adult, and F = fecundity of a breeding pair during their life. For larvae:

$$S_L = S/Se = 2/SeF$$

where S_L = survival from larvae to adult, and Se = survival from egg to larvae. The number of entrained larvae (Ne) can be multiplied times S_L to produce and equivalent number of adults (Na) or:

$$Na = S_L N_L$$

Finally, this information can be compared to catch statistics or monetary value to provide some evaluation of the importance of the loss of these adults from the population.

Data Gaps

A variety of data gaps (Table 47) exist in our understanding of the early-life and adult stages of fishes that inhabit waters of the upper Mississippi River. This severely restricts accurate evaluation of the projected short and long-term impacts of hydropower development on fish recruitment and population stability. The most basic data gaps is the lack of an accurate, quantitatively valid estimate of the numbers of eggs and larvae that presently drift in main channel waters of the upper Mississippi River (Data Gap 1) and of the percentage that will be diverted through the hydropower units (Data Gaps 2 and 3). Detailed data on diel variations in either of these values do not exist. A predictive model to help estimate total numbers in the drift, and the timing of peak drift density which incorporates physical and chemical parameters that can be monitored is unrefined for the river (Data Gap 4). This severely limits impact and mitigation analyses.

Table 47. Data gaps pertinent to the evaluation of the impacts of hydropower development on ichthyoplankton drift on the upper Mississippi River.

Data Gap

1. Total drift through present lock and dam systems.
2. Changes in total numbers drifting through the dam caused by changes in current directions and velocities.
3. Numbers that would pass through unit.
4. Physical and chemical parameters that influence amount of total drift.
5. Percent of total larvae of a species that actually would be a component of the drift.
6. Methods to evaluate mortality of eggs and larvae collected in the UMR.
7. Mortality caused by present system.
8. Mortality caused by passage through hydropower unit.
9. Mortality caused by changes in tailwater hydrology and water quality (i.e. gas saturation).
10. Influence of sublethal damage and disorientation on predator-prey functions.
11. Mortality budgets of high impact species.
12. Stock-recruitment functions of RIFS.
13. Long range impacts on population levels of various levels of increased loss of eggs and larvae.
14. Adequate quantification of adult population sizes, population trends, and present stresses.

After the number of larvae that pass through the hydropower unit has been determined, it becomes important to determine a number of variables related to the analysis of the importance of the potential loss of those individuals from the population. Depending on the method to be used for impact analysis, a method to evaluate mortality of eggs and larvae may be needed to be developed for the UMR (Data Gap 6). The highly productive, turbid waters of the system and short-term nature of possible studies do not lend themselves to dilution table methods employed in fixed-site impact studies (i.e. power plant entrainment). The mortality caused by the present dam system, the hydropower unit itself, or caused as a result of changed hydrology are unknown (Data Gaps 7-9). The degree of delayed mortality is also unknown (Data Gap 10). These sorts of mortality values may be extremely difficult to determine and, as discussed previously, it may be more practical to assume that the present dam system causes no mortality, while the proposed hydropower units would cause 100% mortality of entrained individuals. If a life table approach is to be employed in the impact analysis, then a complete mortality budget for each RIFS would be necessary (Data Gap 11). Again, these sorts of data are extremely difficult to obtain for species of riverine fishes. Whether a life table approach, stock-recruitment approach (Data Gap 12), or equivalent adult method is employed to assess impacts, there are very few data to provide a quantitatively valid estimate of the long range impacts of various levels of ichthyoplankton loss to the population (Data Gap 13). The equivalent adult method perhaps has the least number of unquantified variables to deal with of all the assessment methods. However, the method does assume that the population is at equilibrium or that at least the degree of change in a population is known. As demonstrated in Section 8 of this report, collection of data on population trends and quantification of the impacts of known stresses on the RIFS populations needs further work (Data Gap 14).

Of the various gaps in data that limit assessment of the potential impact of hydropower development on ichthyoplankton survival, recruitment, and ultimately population levels, several are critical. If an equivalent adult method of impact assessment is to be employed then information on (1) total drift presently passing through the dam (Data Gap 1), (2) any changes in total numbers flushed through the dam because of hydropower-related changes in hydrology (Data Gap 2), (3) an estimate of the numbers that might pass through the unit (Data Gap 3), and (4) a more extensive evaluation of the stability of present RIFS populations is needed. Secondarily, data on the percentage of larvae of a species that is actually in the drift (Data Gap 5) may add to the impact assessment. Should the worse-case assessment of 100% mortality prove unacceptable, then further evaluation of mortality may be required. If the assessment indicates that mitigation methods may be necessary then the evaluation of physical and chemical parameters that determine the timing and amount of drift will be needed.

Methods to Quantify Ichthyoplankton Drift

Ichthyoplankton can be collected by a variety of gears which primarily include towed nets, stationary nets, and pumps. Of these major types of sampling gear, only the stationary net specifically collects drifting organisms. The other types of gear collect nondrifting individuals in addition to drifting individuals.

Plankton nets of various sizes and meshes are employed to collect ichthyoplankton. When towed, the efficiency of nets is a function of the diameter of the net mouth. Larger nets should be more efficient because of the reduced ability of larvae to avoid the net. However, Bowles et al. (1978) questioned this assumption. Conical nets with 1-m diameters (3:1 length to diameter ratio) are often towed to collect ichthyoplankton in rivers and deep lakes as are nets with 1/2-m diameters. If stationary sets are employed to collect passively drifting individuals, nets of either diameters should be similar in their efficiencies. The larger diameter net will collect more larvae than will the smaller net for a given duration of set, but large nets are proportionally more expensive and more difficult to handle. The 1/2-m-diameter is recommended for most sampling. If the target species, however, is suspected to drift near the substrate (e.g., sauger), then a net with a squared-off mouth opening should be employed to more efficiently sample that portion of the water column. Species such as channel catfish are not collected efficiently with either gear and large sets with trawls open to the current might be used. Estimates of the water filtered by all nets should be made with the aid of an in-net, impeller-type flow meter. Out-of-net current measurements coupled by duration of set do not properly estimate the volume of water filtered by a net. The indirect method of estimating the volume sampled usually overestimates the volume and underestimates the density of larvae present. A variety of net mesh sizes can also be used, but the one most commonly used and of greatest applicability to ichthyoplankton collections in the UMR is the 500 μm-mesh size.

Vertical and horizontal variations in ichthyoplankton densities occur in the main channel. Two main sampling designs that takes into account these variations can be used to sample the water mass to provide an accurate estimate of total drift. The cross-sectional plane of the main channel can be divided horizontally and vertically into discrete "pockets" of water as was done by Hazleton (1978) for the Commonwealth Edison Company Quad-Cities Station in Pool 14 (Figure 17). Each "pocket" is then sampled for ichthyoplankton density and flow, and an estimate of total drift can then be obtained. This is the most detailed method of total drift estimation and the most labor intensive and expensive. Another method combines integrated sets in each designated vertical column. This provides fewer samples, requires less sorting, and less time to process samples, but sacrifices much critical information and is not recommended for this study.

Very significant diel variations in drift densities exist which must also be considered in the sampling program. Samples must be taken over a variety of times during the day. Studies discussed earlier have shown that drift densities usually peak at dusk and dawn, although peaks for some species may occur at midnight. Sampling periods must be frequent enough to incorporate all these times. We suggest that sampling once every 4 hours should be sufficient.

To accomodate seasonal variations in drift composition and intensity, sampling should oegin in early-April. It does not appear necessary to continue sampling past late-July. At the minimum, sampling should be done at least biweekly until water temperatures reach 17°C. As the water warms past this point, drift densities and the species diversity will increase significantly and weekly sampling is then recommended.

Recommended Approaches

To accommodate time and funding constraints, we recommend that studies be designed to address three of the critical data gaps (Table 47) which presently limit an accurate assessment of the impacts of hydropower development. These data gaps are as follows: (1) total drift through the present system, (2) changes in numbers which may pass through the dam because of changes in current directions and velocities, and (3) adult population sizes, trends, and stresses. If funding permits, information on the percent of total ichthyoplankton that is actually a component of the drift and can be evaluated from the existing literature. Data Gap 1 will require a vertical/horizontal sampling scheme that evaluates seasonal and diel variations in drift as discussed earlier. No accurate evaluation of hydropower impacts can be made without these data. We recommend that samples of ichthyoplankton, current, and temperature be taken from the cross-section immediately above and below each lock and dam of concern.

All of these data can then be applied toward projected changes in current to predict minimum changes in drift patterns in the vicinity of the hydropower unit (Data Gap 2). Projected changes in the drift from proximal backwater areas (e.g. Lake Onalaska) can also be estimated. Given the above information, estimates of diel and seasonal changes in numbers and in the composition of drift passing through the turbines can follow (Data Gap 3). We do recommend that the drift data be compared to the nondrift component of each RIFS. We believe this information can be provided without an excessive increase in labor. After numbers that pass through the hydropower unit have been determined, their loss can be translated to "equivalent adults". If the loss of eggs and larvae translates into an unacceptable loss of adults, then some form of mitigation or enhancement package is recommended.

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11. GLOSSARY

Adhesive - referring to eggs, those which stick to each other or a substrate after water hardening (Auer 1982).

Adult - Sexually mature as indicated by production of gametes (Jones et al. 1978).

Demersal - referring to an egg which rests upon the substrate as a result of deposition or settling (Auer 1982).

Diel - involving a 24-hour period.

Entrainment - the act of drawing an organism into a water intake structure as part of the volume it occupies.

Impingement - occurs when the entrapped organism is held in contact with the intake screen.

Juvenile - young fish after attainment of minimum adult fin ray counts and before sexual maturation (Jones et al. 1978).

Larvae - young fish between time of hatching and attainment of minimum adult fin ray counts (Jones et al. 1978).

Litho-pelagophil

Non-guarder-open stratum - Eggs are deposited on rocks or gravel, but larvae become buoyant and water currents carry them downstream (Balon 1975).

Lithophil

Non-guarder-open stratum - Eggs are deposited on rocks, etc. Larvae are highly photophobic.

Guarder-nest spawner - Eggs are deposited in a single-layer or multi-layer on cleaned areas of rocks or in pits in gravel (Balon 1975).

Mesolarval period - characterized by the absence of distinct principal rays in the median fins. Transition to the metalarval phase requires (1) the full complement of principal rays in the median fins and (2) the pelvic buds or fins must be present (Synder 1976).

Metalarval period - characterized by the full adult complement of principal rays in each of the median fins and by the presence of pelvic fins or buds (Synder 1976).

Oblique tow - Technique used to sample the entire water column. The gear is towed at an angle through the water while the depth is continuously decreased from the bottom to the surface.

Oil globule(s) - discrete sphere(s) of fatty material within the yolk (Jones et al. 1978)

Pelagic - floating free in water column; not necessarily near the surface (Jones et al. 1978)

Pelagophil

Non-guarder-open stratum - Nonadhesive eggs are released and scattered in the open water column. Near neutral or positively buoyant eggs. Larvae swim constantly are positively phototrophic (Balon 1975).

Photophobic - exhibiting an avoidance to light.

Phototrophic - capable of undergoing phototropism.

Phototropism - exhibiting a response to light intensity.

Phyto-lithophil

Non-guarder-open stratum - eggs are deposited on submerged vegetation or logs, gravel, rocks. Many of the species have larvae with cement glands. Larvae usually closely associated with vegetation (Balon 1975).

Phytophil

Non-guarder-open stratum - eggs are adhesive and attach to vegetation, logs, etc. Larvae have cement glands and are not photophobic.

Guarder-substrate chooser - Adhesive eggs are scattered or attached to vegetation. Male guards the nest. No cement glands. Larvae swim instantly to avoid anoxic mud bottoms.

Guarder-nest spawner - members are adapted to nesting above or on a mud bottom (Balon 1975).

Protolarval period - characterized by the absence of distinct spines or rays in the median fins. Transition to the mesolarval stage is based on at least one such ray or spine in the future median fins (Synder 1976).

Psammophil

Non-guarder-open stratum - eggs are adhesive and scattered on sand or roots. Larvae are photophobic (Balon 1975).

Spatial - in reference to ichthyoplankton studies - distribution with respect to space, location, or habitat.

Speleophils

Guarder-nest spawner - eggs are deposited and guarded in natural holes or cavities or in specially constructed burrows (Balon 1975)

Temporal - in reference to ichthyoplankton studies - distributions with respect to season.

Yolk-sac larva - a larval fish characterized by the presence of a yolk-sac (Jones et al. 1978).

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